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Gas Consumption and Metropolitan Economic Performance: Models and Empirical Studies from Guangzhou, China

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ABSTRACT

This study builds a theoretic model to estimates the relationship between gas consumption and metropolitan economic performance with annual data from 1978 to 2013 for Guangzhou in China. Based on Granger causality test with vector error correction model, empirical results show that there is Granger causality from gross domestic product to gas consumption for long run in Guangzhou.

Keywords: Gas Consumption, Metropolitan Performance, Guangzhou
JEL Classifications: C5, E1, Q4, R1

1. INTRODUCTION

There are many studies which examine nexus between gas consumption and economic growth empirically but not many which constructs theoretic model to discuss the mechanism between gas consumption and economic growth. So, the objective of the paper is to examine the relationship between these two variables theoretically and empirically. In empirical part, we focus on the Granger causality nexus between the gas consumption and economic growth in Guangzhou of China from 1978 to 2013.

The nexus between gas consumption and metropolitan economic performance vary substantially across regions. Metropolitan economic growth is affected by factors of production and gas consumption. Research to date indicates that econometric studies of gas consumption and economic growth frequently yield notably different results. One metropolitan economy in China for which such research has yet to be completed is Guangzhou. Because it is the third largest urban economy, that is a surprising omission from the regional economics literature.

With a history of over 2100 years, Guangzhou was a commercial and free trade center in south China. However, the communist party leadership from 1949 to 1977 led to a collectivism ideological orientation, so the metropolitan economy with free trade and commercial activities is being abolished in Guangzhou. The major breakthrough for Guangzhou's repositioning as a regional hub was based on the reform and open-door policy introduced in 1978. Since then Guangzhou has experienced far-reaching transformations of great economic system and industrial structure and rapid urbanization in terms of economic growth and electricity consumption. Comparing to Beijing and Shanghai, Guangzhou is the third biggest city in China and the per capita disposable income of urban residents in Guangzhou was the highest, suggesting that Guangzhou has greater potential for the gas consumption.

The objective of this study is to analyze the nexus between gas consumption and economic performance in Guangzhou. To achieve that goal, the optimal growth model including gas usage is modeled that may be useful for other cities. The causality between electricity consumption and economic performance in the short run and in the long run is modeled using the Granger Cause Test based on the vector error-correction approach, modified unit root tests with break points, and autoregressive distributed lag (ARDL) bounds test approach to cointegration for a 36-year sample period covering 1978 through 2013. As an expanding urban economy whose nexus between gas consumption and economic performance has not been analyzed very extensively, a study of this nature for Guangzhou may yield interesting insights that are useful to analysts and decision makers. Gas consumption in Guangzhou is an area of ongoing research.

The next section provides a brief overview of prior studies that analyze the relationship between gas consumption and economic growth. Those studies cover various sample periods and geographical regions, and employ somewhat different empirical methodologies. Section three builds the theoretical framework that modifies Solow model and explains the interact mechanism between gas consumption and economic growth. Section four summarizes the data structure used to carry out the econometric analysis and empirical results obtained. A conclusion of the paper is in the end.

2. LITERATURE REVIEW

The literature has identified four possible hypotheses on the possible existence and nature of the nexus between gas consumption and economic performance. The first hypothesis is the conservation hypothesis that means unidirectional causality running from economic growth to gas consumption. On the contrary, the growth hypothesis postulates that there is unidirectional Granger causality running from gas consumption to economic growth. The third is the feedback hypothesis, where a bidirectional causality that gas consumption and economic growth are mutually influenced. The fourth view is the neutrality hypothesis of no direct causal links between gas consumption and economic performance.

In terms of the conservation hypothesis, Das et al. (2013) examines the causal relationship between the consumption of natural gas and gross domestic product (GDP) in Bangladesh over the period 1980-2010. They find that there is a positive unidirectional causality running from GDP to natural gas consumption: Movements in GDP affect the consumption of natural gas but not vice-versa. Rafindadi and Ozturk (2015) suggest that economic growth has an effect to natural gas consumption for Malaysian time series data from 1971 to 2012.

In order to test the growth hypothesis, Shahbaz et al. (2013) finds natural gas consumption, capital, labor and exports are positively affecting economic growth in Pakistan. Destek (2016) examines the relationship between natural gas energy consumption and economic growth in 26 Organization for Economic Co-operation and Development countries within a multivariate production model from 1991 to 2013. The vector error correction model (VECM) Granger causality test reveals unidirectional causality from natural gas consumption to GDP growth, which supports the growth hypothesis for the short run. Furuoka (2016) indicates the existence of a unidirectional causality from natural gas consumption to economic development, which was in line with the growth hypothesis for China in the period of 1980-2012.

The feedback hypothesis is tested by Apergis and Payne (2010), they reports for a panel of 67 countries within a multivariate framework over the period 1992-2005, the results of the panel VECM reveal bidirectional causality between natural gas consumption and economic growth in both the short and long run. Solarin and Shahbaz (2013) support the presence of feedback hypothesis between natural gas consumption and economic growth in Malaysia for the period of 1971-2012. Shahbaz et al. (2014) examines the dynamic relationship between natural gas consumption and economic growth in Pakistan using a multivariate model by including capital and labor as control variables for the period between 1972 and 2011. The results of causality test suggest that natural gas consumption and economic growth are complements. Ozturk and Al-Mulali (2015) find the results from the Granger causality test revealed bidirectional causality between natural gas energy consumption and GDP growth which confirms the feedback hypothesis in Gulf Cooperation Council countries taking the period of 1980-2012.

The fourth view is the neutrality hypothesis of no direct causal links between energy (gas) consumption and economic performance (Sharmin and Khan, 2016). Recently, Solarin and Ozturk (2016) examine the relationship between natural gas consumption and economic growth in 12 OPEC member countries for the period of 1980–2012. Their findings show the evidence of feedback relation between natural gas consumption and economic growth in OPEC members as a panel. However, diverse results are obtained when the member countries are individually examined. The results provide evidence for growth hypothesis in Iraq, Kuwait, Libya, Nigeria and Saudi Arabia, but conservation hypothesis in Algeria, Iran, United Arab Emirates and Venezuela. Further evidence suggests the existence of neutrality hypothesis in Angola and Qatar; and feedback hypothesis in Ecuador

According the literature above, the nexus between gas consumption and economic growth has been extensively studied but the evidence so far is contradictory and inconclusive. Most of the scholars above just make good use of the national level data without any theoretic model to explain the interact mechanism between these two variables. Comparing to the current studies, the authors of this paper try to concentrate on using the data from the metropolitan level in and consider the theoretic model modifying Solow growth theory.

3. THEORETIC MODEL

The neoclassical optimal growth model that we apply is originally introduced by Solow (1956). But comparing with his model that focuses on optimal growth rate, we focus on income elasticity of gas consumption. So we assume the long run economic growth function with the technology A and per capita capital $k(= K/L)$ is $y = AkLX$. Here, $y(= Y/L)$ is per capita output, K represents total capital, L represents total labor, X represents total gas consumption. And then, gross output Y is the functional of total gas consumption $X(= Lx)$: $Y = AKLX$, $\frac{\partial Y}{\partial X} = AKL > 0$. The economic implication is that being the input of long run gross production function, gas plays a key role in propelling gross output. That is to say, the gross gas consumption will likely improve gross output in the long term.

Furthermore, when we denote labor grows as $\frac{dL/dt}{L} = n\ (n > 0)$, we can obtain the dK/dt by differentiating $K(t) = k(t)L(t)$: $\frac{dK}{dt} = L\frac{dk}{dt} + k\frac{dL}{dt} = L\frac{dk}{dt} + knL$.

On the other hand, when I represents gross investment and S represents gross saving, and the rate of capital depreciation is $\delta \geq 0$, according to the capital stock identity $K(t) = K(t-1) + I - \delta K$ and macroeconomic equilibrium ($I = S$), we get $\frac{dK}{dt} = \frac{K(t) - K(t-1)}{t-(t-1)} = S - \delta K$.

So, $L\frac{dk}{dt} + knL = \frac{dK}{dt} = S - \delta K$. And through saving function $S = Y - C$, and then $L\frac{dk}{dt} + knL = Y - C - \delta K$, so $\frac{dk}{dt} = y - tc - (n+\delta)k = y - (oc + c) - (n+\delta)k$, where tc is per capita total different kinds of consumption.

3.1. Short Run Scenario $\frac{dk}{dt} = 0$

In terms of the aggregate demand side, the gas price (p) is the decreasing functional of gas consumption amount x ($p = p(x)$, $p/(x) < 0$) in short run, from $\frac{dk}{dt} = 0$, we get $y = (oc + xp(x)) + (n + \delta)k$. From $\frac{\partial y}{\partial x} = p(x) + xp^{'(x)}$, we get a corollary:

Corollary 1: If $|p(x)| > |cp^{'(x)}|$, then $\frac{\partial y}{\partial x} > 0$. If $|p(x)| \leq |xp^{'(x)}|$, then $\frac{\partial y}{\partial x} \leq 0$.

3.2. Long Run Scenario $\frac{dk}{dt} \neq 0$

From equation $\frac{dk}{dt} = y - (oc + xp(x)) - (n+\delta)k$, we get $\frac{dk}{dt} + (n+\delta)k = y - (oc + xp(x))$, which is the linear differential function of k.

So, we get

$$k(t) = e^{-\int(n+\delta)dt}\{\int[y - (oc + xp(x))]e^{\int(n+\delta)dt} + \varepsilon\}$$

$$= e^{-(n+\delta)t}\{\int[y - (oc + xp(x))]e^{(n+\delta)t} + \theta\}$$

$$= e^{-(n+\delta)t}\left[\frac{y - (oc + xp(x))}{n+\delta}e^{(n+\delta)t} + \theta\right]$$

$$= \frac{y - (oc + xp(x))}{n+\delta} + \theta e^{-(n+\delta)t}$$

and θ is the constant.

And then from aggregate supply side, the long run production $y = ALkX = ALX\left[\frac{y - (oc + xp(x))}{n+\delta} + \theta e^{-(n+\delta)t}\right]$, hence

$$y = ALX\left[\frac{y - (oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}}{n+\delta}\right]$$

$$y(n+\delta) = ALX\left[y - (oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right]$$

$$= ALXy - ALX\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right]$$

$$ALX\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right] = ALXy - y(n+\delta) = y\left[ALX - (n+\delta)\right]$$

$$y(t) = \frac{ALX\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right]}{ALX - (n+\delta)}$$

$$= \frac{AL^2x\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right]}{AL^2x - (n+\delta)}$$

So

$$\frac{\partial y}{\partial x} = \frac{\left\{AL^2\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right] + AL^2x\left[p + xp'(x)\right]\right\}\left(AL^2x - n - \delta\right) - AL^2\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right]}{\left(AL^2x - n - \delta\right)^2}$$

So, we could obtain the second corollary:

Corollary 2: If

$$\frac{\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t} + x\left[p + xp'(x)\right]\right]}{\left(AL^2x - n - \delta\right) > \left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right]}, \frac{\partial y}{\partial x} > 0\text{; If}$$

$$\frac{\left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t} + x\left[p + xp'(x)\right]\right]}{\left(AL^2x - n - \delta\right) \leq \left[(oc + xp(x)) + (n+\delta)\theta e^{-(n+\delta)t}\right]}, \frac{\partial y}{\partial x} \leq 0$$

4. EMPIRICAL TESTS

4.1. Data Sources and Statistic Description

Actually, there are a lot of types of gas consumption to be tested. In this part, we just select liquefied petroleum gas consumption that is a typical gas uses as the gas consumption variable. The time series data about the liquefied petroleum gas consumption of Guangzhou are from 1978 to 2013. The time series data about the GDP, capital and labor are obtained from the Guangzhou Statistical Yearbooks from 2000 to 2014. The direction of causality between liquefied petroleum gas consumption and metropolitan economic performance in the light of the literature overview is not consistent and depends on different datasets, the characteristics of different countries and the different econometric methodologies applied.

4.2. Variable Descriptions and Summary Statistics

Table 1 lists all variables and their definitions used in the empirical analysis.

Table 2 lists summary statistics for every variable included in the sample. As shown by the information contained in Table 2, the sample data exhibit good variability.

4.3. Empirical Results

4.3.1. Unit root tests

1. Augmented Dickey–Fuller (ADF) test:
   Standard Granger causality tests (Granger, 1969) have to be conducted on stationary time series. Following this line, we first test the unit roots of X_t to confirm the stationary properties of each variable. This is achieved by using the ADF test. ADF test is applied to detect the possible presence of unit roots in GDP, CAPITAL, LABOR and GAS. The null hypothesis of unit root can be rejected in favor of the alternative hypothesis of no unit root when the absolute value of ADF-test statistic is greater than the absolute value of critical value. The results in Table 3 show that all variables are non-stationary in their levels since the absolute values of test statistics for each variable are smaller than 5% or 1% critical values. On the other hand, GDP, CAPITAL, LABOR and GAS are stationary processes in their first differences because the absolute values of test statistics for each variable are greater than critical values. Specifically, the absolute values of test statistics for ΔGDP and ΔLABOR are >1% critical values, and the absolute values of test statistics for ΔGAS and ΔCAPITAL are >5% critical values.

Table 1: Variable definitions

Variable	Mnemonic	Definition	Unit
Metropolitan Economic Performance	GDP	Annual GDP in Guangzhou	10,000 Yuan RMB
Liquefied Petroleum Gas Consumption	GAS	Total annual consumption of liquefied petroleum gas in Guangzhou	Ton
Capital	CAPITAL	Total annual social investment in fixed assets	10,000 Yuan RMB
Employment	LABOR	Total annual number of employed persons	Person

GDP: Gross domestic product

Table 2: Descriptive statistics

Variable (unit)	CAPITAL (Yuan)	GAS (Ton)	GDP (Yuan)	LABOR (Person)
Mean	8,849,420.0	334,935.7	32,640,204	4,496,783.0
Median	4,848,886.0	138,017.5	13,636,309	3,921,366.0
Max	39,909,035	1,087,687.0	1.54E+08	7,599,295.0
Min	67,021.00	498.0000	430,947.0	2,668,989.
Standard deviation	11,012,104	410,753.1	43,093,092	1,548,260.0
Skewness	1.363482	0.858007	1.447263	0.683430
Kurtosis	3.865252	1.921527	3.990586	2.192732
Observation	36	36	36	36

GDP: Gross domestic product

Table 3: ADF unit root test results

Levels				First differences			
Variables	ADF-test statistics	Lag length	Critical values	Variables	ADF-test statistics	Lag length	Critical values
GDP	3.230568	10	−3.670170***	ΔGDP	3.603854	9	−2.660720***
CAPITAL	1.557285	9	−3.595026**	ΔCAPITAL	2.616327	8	−1.954414**
LABOR	−0.090163	2	−4.262735***	ΔLABOR	−6.714992	1	−4.262735***
GAS	−2.062377	1	−3.548490**	ΔGAS	−3.908611**	0	−3.548490**

*Significance at 10% level, **Significance at 5% level, ***Significance at 1% level. GDP: Gross domestic product, ADF: Augmented Dickey–Fuller

Table 4: Perron's modified ADF unit root test results

Break type: Innovative outlier				Break type: Innovative outlier			
Variables	t-statistic	Break data	Critical values	Variables	t-statistic	Break data	Critical values
GDP	0.665067	2003	−4.949133***	ΔGDP	4.739230	2009	−4.734858***
CAPITAL	−0.857716	2005	−4.949133***	ΔCAPITAL	−6.216286	2010	−5.347598***
LABOR	−0.0583589	2000	−4.949133***	ΔLABOR	−8.268623	1995	−4.949133***
GAS	−2.275418	2006	−4.734858***	ΔGAS	−6.474207	2003	−4.949133***

***Significance at 5% level, Innovative outlier affecting every member of a set of autoregressive time series at the same time point are represented as independent random effects.
GDP: Gross domestic product, ADF: Augmented Dickey–Fuller

Table 5: Zivot-Andrews's structural break trended unit root test results

Variables	At level			Variables	At first difference		
	t-statistic	Break data	Critical values		t-statistic	Break data	Critical values
GDP	0.819534	2000	−5.34***	ΔGDP	−8.341381	2003	−4.80***
CAPITAL	1.733337	2008	−5.34***	ΔCAPITAL	−4.893687	2006	−4.80***
LABOR	−1.538234	2005	−5.34***	ΔLABOR	−7.823767	2000	−5.34***
GAS	−3.241393	1997	−4.11*	ΔGAS	−4.830692	2006	−5.34*

*Significance at 10% level, **significance at 5% level, ***significance at 1% level. GDP: Gross domestic product

2. Perron's modified ADF test with exogenous breakpoint:
   Perron's computation of modified Dickey-Fuller tests allows for levels and trends that differ across a single break date (Perron, 1989). Table 4 reports that all variables are integrated of I(1) and thus stationary in first difference, comparing the absolute values of test statistics for each variable with the 5% critical values.
3. Zivot and Andrews's test by break data endogenously:
   The results of Zivot and Andrews test (1992) are detailed in Table 5 which shows that non-stationary process is found in all series at level with intercept and trend but variables are found to be stationary at first difference. This confirms that GDP, CAPITAL, LABOR and GAS are integrated at I(1).

4.3.2. Cointegration tests

According to the unit root test results, integration of the variables is of the same order. We continued to test whether these variables are cointegrated over the sample period.

1. Johansen cointegration test:
   Table 6 shows the results of the Johansen test (1991). Because the test rejects the hypothesis of no cointegration at the 5% significance level, i.e., there may be a long run relationship among GDP, CAPITAL, LABOR, and GAS for Guangzhou.
2. ARDL bounds test approach to cointegration:
   Armed with information about stationarity, we apply the ARDL bounds testing approach to cointegration. The results of the bound test (Pesaran et al., 2001) are given in Table 7. From these results, it is clear that there is a long run relationship among the variables when GDP, GAS, LABOR and CAPITAL are the dependent variable, because their F-statistic are higher than the upper-bound critical value at the 5% level. This implies that the null hypothesis of no cointegration among the variables are rejected, when GDP, GAS, LABOR and CAPITAL are dependent variables.

Table 6: Johansen cointegration test results

Hypothesized number of cointegrating equation	Trace statistic	5% Critical value
None**	113.3784	47.85613
At most 1	26.36795	29.79707
At most 2	7.294706	15.49471
At most 3	1.536720	3.841466

**Significance at 5% level

Table 7: Bounds test results

Bounds testing to cointegration		
Estimated model	**Lag length**	**F-statistic**
f (GDP/GAS, CAPITAL, LABOR)	(4,4,3,4)	12.09231**
f (GAS/GDP, CAPITAL, LABOR)	(1,4,3,4)	5.806499**
f (CAPITAL/GDP, GAS, LABOR)	(4,4,4,4)	5.826673**
f (LABOR/GDP, GAS, CAPITAL)	(4,3,4,3)	7.942715**
5% critical values	I (0)	I (1)
	2.79	3.67

**Significance at 5% level. The estimated models just show which is the dependent variable. GDP: Gross domestic product

4.3.3. Granger causality analysis: Based on VECM in the long run and short run

After we find the existence of cointegration among the variables, the next step is to estimate the short and long run direction of causality between GDP, CAPITAL, LABOR, and GAS. Table 8 reports the short and long run coefficients for GDP, CAPITAL, LABOR and GAS.

Considering the long run, we find there is no Granger causality from GAS to GDP since the coefficient of ECM_{t-1} when the ΔGDP as dependent variable is positive and statistically significant for long run. Furthermore, there is Granger causality from GDP to GAS at 10% level of significance for long run, since the coefficient of ECM_{t-1} when the ΔGAS as dependent variable is negative and statistically significant for long run.

According to the theoretic model in the second part, the economic implication of the GDP Granger causes GAS is that being the luxury goods, households and industries can consume more gas, following metropolitan economy growing. Actually, before 1978, Guangzhou still enforced planning economy system, which resulted in low total income for the whole society and serious public financial deficit for local government. Additionally, the shortage of gas infrastructure is because of lack of infrastructure investment. However, after openness and reform policy of 1978 in China, market system was gradually introduced into Guangzhou, so the metropolitan economy including total income and public financial revenue grows dramatically, and then gas consumption increases greatly with the complement to gas infrastructure invested by the local government.

In short, empirical results support the evidence of "GDP Granger causes GAS" for long run in Guangzhou, which is consistent with conservation hypothesis.

5. CONCLUSION AND POLICY IMPLICATION

To analyze the nexus between gas consumption and metropolitan economic performance in Guangzhou City of China, econometric models are utilized with and without break date. The results of Granger causality test in VECM show that

Table 8: VECM Granger causality analysis

Dependent variable	Type of causality				
	Short run				Long run
	$\Sigma\Delta GDP_{t-1}$	$\Sigma\Delta GAS_{t-1}$	$\Sigma\Delta \text{CAPITAL}_{t-1}$	$\Sigma\Delta \text{LABOR}_{t-1}$	ECM_{t-1}
ΔGDP_t	-	−2.726136 (0.527417)	1.234252***(13.85917)	−1.115867 (1.129039)	0.432763*** (726.9082)
ΔGAS_t	0.007026 (0.131593)	-	0.069837** (5.950379)	0.033777 (0.138727)	−0.002282* (2.709336)

*Significance at 10% level, **Significance at 5% level, ***significance at 1% level. Values in parenthesis are P values for Wald test based on Chi-square distribution. VECM: Vector error correction model, GDP: Gross domestic product, ECM: Error correction model

GDP Granger causes gas consumption, which is statistically significant for long run.

We thus propose policy suggestions to solve the gas and sustainable development dilemma in Guangzhou as: Enhancing gas supply security and guaranteeing gas supply, especially to provide adequate gas power supply and set up metropolitan strategic gas reserve; enhancing gas efficiency to save gas.

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