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Gasoline consumption in China: a dynamic panel data analysis

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Abstract

In this article, the relationship between gasoline consumption, real GDP, real gasoline price and road infrastructure in China is re-estimated in order to update and extend the estimates documented in the literature. Panel data for 17 Chinese provinces from 2003 to 2009 are analyzed under a recently proposed dynamic general method of moments (GMM) estimation technique. The long-run income and price elasticities are estimated to be 1.10 and -0.17, respectively.

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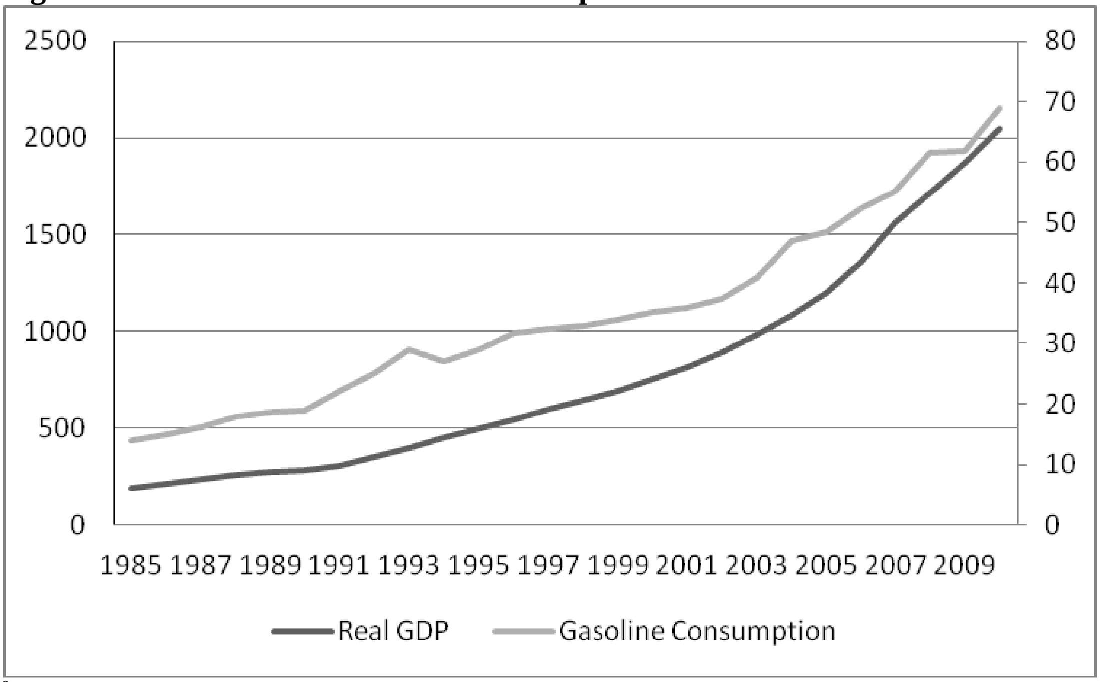
1. Introduction

Gasoline is the second most important oil product in terms of consumption level in China. Apart from a negligent amount that is consumed for private power generation, practically all the gasoline consumed in China is for transport purposes. Thanks to the rapid growth in personal income and the *1994 Auto Policy* (Leung, 2010) that encourages private automobile ownership, Chinese gasoline consumption more than doubled from 29.09 million tons in 1995 to 68.86 million tons in 2010. Given the potential growth of the Chinese economy and the further developments in the road infrastructure, gasoline demand in China is set for continual growth. An understanding of the effects of income and gasoline price on gasoline consumption for the country is important for policymakers, energy analysts and economic modellers. Figure 1 shows the real GDP and gasoline consumption of China. It can easily be observed that gasoline consumption tracks real GDP very closely through the years.

Figure 1. Real GDP and Gasoline Consumption in China[a]



[a] The primary axis refers to the real GDP index (base=100 in 1978). The secondary axis refers to gasoline consumption in million tons.

There is an extensive literature on the estimation of price and income elasticities of gasoline demand in the past two decades (e.g. Bentzen, 1994; Eltony and Al-Mautairi, 1995; Ramanathan, 1999; Alves and Bueno, 2003; Cheung and Thomson, 2004; Polemis, 2006; Flood et.al, 2010). These studies confirm the existence of cointegration between gasoline demand and its economic determinants and apply the error-correction model to estimate the long-run and short-run elasticities. In general, gasoline demand is found to be price-inelastic, income-elastic and the price elasticity measure is higher in the long-run. Amongst these studies, only Cheung and Thomson (2004) estimate the gasoline demand elasticities for China.

The improving provincial data reporting standard in China and the continual development in panel data estimation techniques opened up an opportunity for the estimation of gasoline demand elasticities under a different data structure. This short article aims at contributing to the literature by employing recent dynamic panel data techniques to re-estimate the relationship between gasoline demand, gasoline price and income. The estimates obtained in this study update the existing estimates in the literature and allow the comparison of outcomes of different estimation techniques. The next section describes the econometric methodology. Section 3 presents and discusses the results. Section 4 discusses some policy implications of the results.

2. Econometric Methodology

We model gasoline demand as a function of price, income and road infrastructure:

$$g_{it} = \alpha_i + \beta' x_{it} + u_{it}, \quad x_{it} = [p_{it}, y_{it}, r_{it}] \tag{1}$$

where g refers to per capita gasoline consumption in ton per person, p is the real price of #93 unleaded gasoline in Reminbi per ton, y is per capita real GDP in Reminbi per person, r is the cumulated length of highways and expressways in kilometers, u is an error term, subscript i denotes the i^{th} province and subscript t denotes the time period. We consider all variables in natural logarithm.

In the applied panel data literature, it is common for researchers to assume a Koyck (1954) adjustment mechanism in the dependant variable and include a lagged dependant variable in the model (see Medlock and Soligo (2001) as an example). Such a model can be estimated by, for example, the Arellano and Bond (1991) and the Blundell and Bond (1998) estimators. In such models, the dynamic panel autoregressive coefficient (ρ) measures the speed of adjustment to all shocks – the higher the value of ρ, the slower is the adjustment. The major advantage of such a specification is that it allows for long-run and short-run interpretations of the estimated coefficients.[1] However, a major drawback of such an approach is that when the series contain a unit root, the Arellano and Bond (1991) estimates are random when the time span is short. Also, when ρ approaches unity, the Arellano and Bond estimator suffers from a weak instrument problem (Blundell and Bond, 1998) which leads to a large downward bias and highly variable estimates of ρ.

This paper applies the GMM dynamic panel data estimator proposed by Han and Phillips (2010). This estimator avoids the weak instrument problem when ρ approaches unity and the inconsistency present in fixed effects estimation of dynamic panel models (Nickell, 1981) for panels with short time span. A practical advantage of this estimator is that there are no restrictions on the number of the cross-sectional units (n) and the time span (T) other than the simple requirement that $nT \to \infty$. Thus, neither large T nor large n is required for the limit theory to hold. Also, Gaussian asymptotics apply irrespective of how the composite sample size $nT \to \infty$, including both fixed T and fixed n cases.

[1] The estimated coefficients are the short-run elasticities while the long-run elasticities can be obtained by dividing the short-run estimates by 1-ρ.

In the case that $u_{it} = \rho u_{it-1} + \varepsilon_{it}$ and $\rho \in (-1, 1]$, equation (1) can be transformed to:

$$g_{it} = (1 - \rho)\alpha_i + \beta'(x_{it} - \rho x_{it-1}) + \rho g_{it-1} + \varepsilon_{it} \qquad (2)$$

where ε_{it} is a white noise. Letting $z_{it} = g_{it} - \beta' x_{it}$, equation (2) can then be written as:

$$z_{it} = (1 - \rho)\alpha_i + \rho z_{it-1} + \varepsilon_{it} \qquad (3)$$

Han and Phillips (2010) show that equation (3) can be transformed to:

$$2\Delta z_{it} + \Delta z_{it-1} - \rho\Delta z_{it-1} = \eta_{it}, \quad \eta_{it} = 2\Delta\varepsilon_{it} + (1 + \rho)\Delta z_{it-1} \qquad (4)$$

When ε_{it} is a white noise, Han and Phillips (2010, p.141) show that Δz_{it-1} and η_{it} are uncorrelated for all ρ. This yields the first moment condition as proposed by Han and Phillips (2010)[2]:

$$E\sum_{t=2}^{T}\Delta z_{it-1}[(2\Delta z_{it} + \Delta z_{it-1}) - \rho\Delta z_{it-1}] = 0 \qquad (5)$$

If we allow α_i to be arbitrarily correlated with x_{it}, then equation (2) can be written as follows by within transformation:

$$\ddot{g}_{it} - \rho\dot{g}_{it-1} = (\ddot{x}_{it} - \rho\dot{x}_{it-1})'\beta + \ddot{\varepsilon}_{it} \qquad (6)$$

where $\ddot{g}_{it} = g_{it} - T^{-1}\sum_{s=1}^{T} g_{is}$, $\dot{g}_{it-1} = g_{it-1} - T^{-1}\sum_{s=1}^{T} g_{is-1}$, and so on.

Since the within-group estimator is efficient when α_i is allowed to be correlated with x_{it}, Han and Phillips (2010) propose the second moment condition as follows:

$$E\sum_{t=1}^{T}(\ddot{x}_{it} - \rho\dot{x}_{it-1})[(\ddot{g}_{it} - \rho\dot{g}_{it-1}) - (\ddot{x}_{it} - \rho\dot{x}_{it-1})'\beta] = 0 \qquad (7)$$

Estimates of ρ and β can be obtained iteratively between equations (5) and (7) until the procedure converges. It should be noted that the model specification under this approach is different from the one derived from the Koyck adjustment mechanism described earlier in this section. Here, ρ measures the speed of adjustment to shocks other than the oil price, income and road infrastructure. Under the Han-Phillips framework, gasoline consumption responds to shocks in these regressors contemporaneously. Therefore, the coefficient estimates obtained in this study should be interpreted as the long-run elasticities.

[2] It should be noted that T+1 periods are observed in the data, from t=0 to t=T.

3. Empirical Analysis

3.1. Data Description

We consider annual data of per capita gasoline consumption, per capita real GDP and real gasoline price for 17 provinces in China from 2003 to 2009.[3] The provinces included in this study are the ones that implement the so called 'one province, one price' policy, such that all the cities within the province apply the same basis price of gasoline for the province. The time span of our study is limited by data availability.

The population, GDP, consumer price index and highway length data are collected from the China Statistical Yearbook (various issues), while the gasoline consumption data are obtained from the China Energy Statistical Yearbook (various issues). The gasoline price series are obtained from the CEIC China Premium Database. The price and GDP data are transformed into real terms by the consumer price index for each province.[4]

Table 1. Estimation results

	Coefficient	**Std. Error**	**p-value**	**95% C.I.**
Lag *g*	0.961	0.252	0.000	(0.466, 1.456)
p	-0.171	0.305	0.576	(-0.769, 0.428)
y	1.104	0.392	0.005	(0.335, 1.872)
r	-0.019	0.116	0.869	(-0.246, 0.208)

3.2. Empirical Results

The estimation results obtained by the Han-Phillips estimator are reported in Table 1. The estimated coefficient for lagged gasoline consumption of 0.96 is statistically significant at the 1% level. The null hypothesis of the existence of a unit root in gasoline consumption cannot be rejected at the 5% significance level. This suggests pronounced persistence in gasoline consumption and provides strong justification for the use of the Han-Phillips estimator. The coefficient estimate of real per capita GDP is 1.10 and it is statistically significant at the 1% level. Since the 95% confidence interval contains 1, we cannot reject the null hypothesis (at 5% significance) that gasoline demand is unit elastic with respect to income. This result is consistent with Figure 1. On the other hand, the coefficient of real gasoline price is -0.17. While this coefficient carries the usual sign, it is not statistically significant at any conventional significance level. It appears that gasoline demand in China is highly price inelastic. There are at least two possible reasons that explain this finding. First, although the continual rise in real gasoline price may reduce the affordability of the product to a certain extent, this effect is more than offset by the rapid growth in household income. Therefore, the income effect of the price change tends to be negligible. Second, the *1994 Auto Policy* may have caused a rather enduring change in transport patterns and

[3] The 17 provinces include Beijing, Gansu, Guangdong, Guangxi, Hainan, Hebei, Heilongjiang, Henan, Hubei, Jilin, Liaoning, Ningxia, Shandong, Shanghai, Shanxi, Tianjin and Xinjiang.

[4] Since the published provincial consumer price indices are calculated with the preceding year as the base year, we made adjustments to convert the base year of these price indices to year 2003 (i.e. 2003 index=100).

reduced the reliant on public transport. This may in turn have dragged the development of a reliable public transport system and eventually limited the viable alternatives available for commuters. As a result, the substitution effect of the price change also tends to be trivial. Given the small income and substitution effects, we may expect the gasoline consumption in China to be price-insensitive.

3.3 Comparative Analysis

Now we compare our estimates to those obtained in earlier studies. The long-run elasticities of those studies are summarized in Table 2. Despite the completely different data structure, time span and estimation approach, our income elasticity estimate is very close to the long-run estimate of Cheung and Thomson (2004). Gasoline demand is also reported to be price inelastic by these authors. However, their long-run price elasticity estimate is larger (in absolute value) and statistically significant at the 10% level. Therefore, our price elasticity result appears to be more "extreme" than those estimated by these authors. This difference may be attributed to the time span covered. Cheung and Thomson (2004) cover the time period of 1980 to 1999 while our study covers year 2003 to 2009. The aforementioned reasons for the price-inelastic Chinese gasoline demand apply entirely to our study period but only partly to the study period of Cheung and Thomson (2004). Hence, it is not too surprising that the gasoline demand is found to be less price-inelastic in Cheung and Thomson (2004). In general, the elasticity estimates in Table 2 vary widely. However, some commonalities can be observed from these results, with only a few exceptions. Firstly, except in Flood et al. (2010) and Alves and Bueno (2003), the reported income elasticities are larger in absolute value than the price elasticities. Secondly, with the exception of Alves and Bueno (2003) and Ramanathan (1999), the income elasticities are reasonably close to unity. Finally all studies find that gasoline demand is price inelastic even in the long-run. In these regards, our results are in line with these earlier studies.

Table 2. Summary of Long-run Elasticities

Study	Country	Period	Income Elasticity	Price Elasticity
Present Study	China	2003-2009	1.10	-0.17*
Flood et al. (2010)	OECD	1978-2003	0.82	-0.88
Polemis (2006)	Greece	1978-2003	0.79	-0.38
Cheung and Thomson (2004)	China	1980-1999	0.97	-0.56
Alves and Bueno (2003)	Brazil	1974-1999	0.12	-0.46*
Ramanathan (1999)	India	1972-1994	2.68	-0.32
Eltony and Al-Mutairi (1995)	Kuwait	1970-1989	0.92	-0.46
Bentzen (1994)	Denmark	1948-1991	N/A	-0.41

* indicates insignificance at any conventional significance level.

4. Policy Implications

The International Monetary Fund forecasts the growth in Chinese real GDP to be about 9% per annum in the next few years. Our income elasticity estimate shows that Chinese gasoline demand will grow with the economy. The Chinese government needs to look for more stable sources of gasoline and/or crude oil supply to satisfy the growing demand. Attempts to curtail gasoline consumption for emissions reduction through gasoline tax will likely be unsuccessful because Chinese gasoline demand is insensitive to price changes. This calls for the development of an extended and reliable public transport system (e.g. mass transport system) in the country so as to broaden the transport alternatives other than private vehicles. Also, since gasoline consumption is found to be highly persistent and the adjustment to policy shocks is expected to be very slow, the Chinese government requires policies with strong and far-reaching impacts if it wants to change the consumption pattern in the country.

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