Causal relationship between motor vehicle ownership and GDP

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Abstract

This paper investigated the causal relationship between motor vehicle ownership and GDP. Due to the high motorcycle ownership in some countries, in this paper, both car ownership and motorcycle ownership were investigated separately. The causality was examined using the data of both Taiwan and Japan. The Granger-causality technique was adopted. When applying the Granger technique, the error-correction model, the ADF test and the co-integrating relationships test were carried out. It was found that there is a unidirectional causality from motorcycle ownership to the GDP, for Taiwan as well as for Japan. This causality indicates that motorcycle ownership enhances the growth of the GDP. However, this finding is reversed for car ownership. This study found that there is a unidirectional causality from GDP to car ownership for Taiwan, meaning that the higher the GDP the higher the car ownership in Taiwan. There is no causality relationship between car ownership and GDP for Japan, probably due to some policy constraints on owning a car in Japan. Our analysis will be useful for checking the policy on motor vehicles and to understand their relationship to a country's economic development.

Key words：Causal relationship, GDP, Motorcycle ownership, Car ownership, Granger's technique.

1. INTRODUCTION

Motor vehicle ownership symbolizes the level of economic development level in a modern society. Car ownership is seen as the main motorization index. However, in some developing countries, motorcycle ownership is also very high such as in Taiwan, where there are about 530 motorcycles per 1000 people. Nevertheless, car ownership also amounts to about 250 cars per 1000 populations. A motorcycle is the first motor vehicle for most young people that just entered the labor market before they can afford a car. As soon as people have enough money, they get rid of their motorcycle and buy a car. This might be why the causal relationship between these 2 types of motor vehicles and the gross domestic product (GDP) are different. Taiwan has one of the highest motorcycle ownerships per capita in the world. Japan has more than 13 million motorcycles, but it has a specific parking place requirement regulation for purchasing a car. As a result, car ownership in Japan is not as high as in other developed countries. Thus, this paper takes Taiwan and Japan as an example for testing the causal relationship between motor vehicle ownership and GDP.

Walter Hook and Michael Replogle (1996) explored the history of motorization in Asia and concluded that the characteristics of cities are based on the different modes of transportation they adopted in the city. The number of motor vehicles in Taiwan has increased very fast, ever faster than the growth in GDP. Case studies of China, Indonesia and Japan indicated that the growth in GDP is a major influence on the level of motorization . Joyce Dargay and Dermot Gately (1999) made growth projections for car and total motor vehicles inventory up to the year 2015 for OECD countries and a number of developing economies, including China, India, and Pakistan. Their projections were based on an econometric model that takes the growth of the car/population ratio (car ownership) as a function of per-capita income. Based on historical data, the relationship between ownership and income levels indicates that as income increases, motor vehicle ownership will increase too. Joyce M. Dargay (2001) examined the effect of income on car ownership. He points out that an increase in income leads to higher car ownership. Most of the relevant studies considered that there exits positive relationship between economic variables and motor vehicle ownership. However, it needs to be clarified if it is the motor vehicle ownership that causes the GDP development or if it is the contrary. R. Ramanathan (2001) adopted the concepts of co-integration and error correction to analyze the long-run relationships between transport performance and other macroeconomic variables in India. The result of his study shows that passenger-kilometer (PKM) in India are likely to increase faster than the GDP, and much faster than urbanization.

Most of the relevant studies considered that growth in income or other economic variables are the main factors positively impacting motor vehicle ownership. The causality test and the co-integration analysis can be adopted to test the causal relationship between motor vehicle ownership and GDP.

2. METHODOLOGY

2.1 Unit-root Tests

The Granger’s test is a convenient approach for testing the causal relationship between two variables. Traditional regression analysis such as ordinary least squares or the generalized-least-squares method, must satisfy the condition that all variables are stationary. The so-called “stationary” time series means that the long trend of the time series doesn’t increase or reduce with time and that the speed of the fluctuation remains steady. There are usually three indictors to judge if variables meet the designation of “stationary”：

$$E(Y_t) = E(Y_{t-s}) = \mu \tag{2.1}$$

$$\mathrm{var}(Y_t) = \mathrm{var}(Y_{t-s}) = \sigma^2 \tag{2.2}$$

$$\text{cov}(Y_t, Y_{t-s}) = \text{cov}(Y_{t-j}, Y_{t-j-s}) = \gamma \quad for \quad all \quad t, t-s \quad and \quad t-s-j \tag{2.3}$$

Where t 、s 、j represent different periods and μ （expected value）、σ^2 （variation）、γ （autocorrelation coefficient）are all finite constants.

Granger and Newbold （1974）discovered that the presence of non-stationary variables might lead to spurious regressions when regressing a series having a unit root onto another is most likely to produce high R^2 and significant t-distribution results even though the two variables are in reality independent. The spurious regression may result in erroneous judgment of empirical results, because there isn't any real causality or rational relationship between the dependent variable and the independent variable in the regression model. Thus it is an indispensable step to test whether the variable is stationary while carrying on the empirical research of the time series variable. This can be accomplished by the so-called unit-root test.

The unit-root test used in this paper is the Augmented Dickey Duller (ADF) test (Engle and Yoo, 1987). This model has three types.

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \tag{2.4}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \tag{2.5}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \tag{2.6}$$

where $\Delta y_t = y_t - y_{t-1}$, y is the variable under consideration, Δ is the first difference operator, ε denotes the random error, t denotes the time trend , and p denotes the number of lagged terms to allow for the existence of autocorrelation in ε_t.

If the result of the ADF test can't be rejected, then that means that there is a unit root. In other words, the series is a non-stationary series. A non-stationary series can be switched to a stationary series. A convenient way of transforming is by using differentiation rather than levels of variables. Before co-integration test, we must select the appropriate lag length. The method commonly used is the Akaike Information Criterion (AIC) (Akaike, 1973) or the Schwarz Information Criterion (SIC) (Schwarz, 1978). In this study, we adopted both methods. If the outcome of both methods has the same minimum lag length, then the minimum lag length is chosen for the test. If their lag lengths are different, then we adopt the Likelihood Ration test to select the better one.

2.2 Co-integration test

The co-integration test is a relatively recent econometric tool used for examining long-run relationships between two or more variables. The co-integration technique was developed by Engle and Granger (1987), Hendry (1986) and Granger (1986) for testing Granger-causality. Co-integration refers to a linear combination of variables that are non-stationary with a relationship between them. In order to be co-integrated the variables must be integrated of the same order. No co-integration implies the lack of a long run equilibrium among the variables. For *k* endogenous variables, each of which has one unit root, there will be 0 to *k-1* co-integrated relationships. This study used the Johansen Maximum Likelihood procedure to test co-integration (Johansen, 1988).

To illustrate the Johansen method, we considered the vector auto-regression（VAR）

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p X_{t-p} + \varepsilon_t \qquad t = 1,2,...,T \tag{2.7}$$

where Y_t （$Y_t = [y_{1t}, y_{2t}, ..., y_{nt}]'$） denotes an $n \times 1$ vector of $I(1)$ with lag length *p*; ε_t is the residual; A_i denotes an *n*×*n* matrix of unknown parameters to be estimated. According to the meaning of the Granger representation theorem, the corresponding vector error correct model （VECM）is shown as：

$$\Delta Y_t = \Pi Y_{t-1} + \Pi_1 \Delta Y_{t-1} + \Pi_2 \Delta Y_{t-1} + ... + \Pi_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \tag{2.8}$$

where $\Pi = \sum_{i=1}^{p} A_i - \mathbf{I}$ ，$\Pi_i = -\sum_{j=i+1}^{p} A_j$. The rank of matrix（Π）decides the number of co-integrating vectors in Y_t .The number of co-integrating vectors (CVs) can be established by λ_{Trace} and λ_{Max} statistics.

2.3 Error correction model

Once a number of variables are found to be co-integrated, there always exists a corresponding error-correction representation which implies that changes in the dependent variable are a function of the level of disequilibrium in the co-integrating relationship, which is captured by the error-correction term, as well as changes in other explanatory variable(s). In other words, the meaning of error-correction is that there is an out-off balance in the t-1 period, which will be corrected at the t period.
To consider the variables in this study, models are shown as follows：

$$\begin{cases} \Delta X_t = \alpha_0 + \alpha_1(\varepsilon_{t-1}) + \sum_{i=1}^{p} \alpha_i \Delta X_{t-i} + \sum_{j=1}^{m} \alpha_j \Delta Y_{t-j} + \varepsilon_{1t} & (2.9) \\ \Delta Y_t = \beta_0 + \beta_1(\varepsilon_{t-1}) + \sum_{i=1}^{p} \beta_i \Delta X_{t-i} + \sum_{j=1}^{m} \beta_j \Delta Y_{t-j} + \varepsilon_{2t} & (2.10) \end{cases}$$

or

$$\begin{cases} \Delta X_t = \gamma_0 + \gamma_1(\varepsilon_{t-1}) + \sum_{i=1}^{p}\gamma_i \Delta X_{t-i} + \sum_{k=1}^{n}\gamma_k \Delta Z_{t-k} + \varepsilon_{3t} & (2.11) \\ \Delta Z_t = \phi_0 + \phi_1(\varepsilon_{t-1}) + \sum_{i=1}^{p}\phi_i \Delta X_{t-i} + \sum_{k=1}^{n}\phi_k \Delta Z_{t-k} + \varepsilon_{4t} & (2.12) \end{cases}$$

where ΔX_t、ΔY_t、ΔZ_t denote the variations of variables X,Y,Z at point t, respectively, α_0、β_0、γ_0、ϕ_0 denote constants, α_1、β_1、γ_1、ϕ_1 denote the adjusted coefficients, ε_{t-1} is used to measure the degree of out-off equilibrium for the long-run equilibrium at t-1 period, p、m、n denote the appropriate lag length of variables X,Y,Z, and ε_{1t}、ε_{2t}、ε_{3t}、ε_{4t} denote the residual of each model.

2.4 Granger's Causality Test

Granger defined the causal relationship among two variables from a point of view of predictability. If we consider X_t 、Y_t as the stationary series, then we can define the following variables：

X^t ： A set of information indicating that X was formed until now(t)
Y^t ： A set of information indicating that Y was formed until now(t)
X^{t-1} ：A set of information indicating that X was formed in the past
Y^{t-1} ：A set of information indicating that Y was formed in the past
σ^2 ：Mean square error of the forecast

According to the above definition there are three Granger causalities：

a. causality

- $\sigma^2(X_t | X^{t-1}, Y^{t-1}) < \sigma^2(X_t | X^{t-1})$ (2.13)

- $\sigma^2(Y_t | X^{t-1}, Y^{t-1}) < \sigma^2(Y_t | Y^{t-1})$ (2.14)

b. feedback

- $\sigma^2(X_t | X^{t-1}, Y^{t-1}) < \sigma^2(X_t | X^{t-1})$ and $\sigma^2(Y_t | X^{t-1}, Y^{t-1}) < \sigma^2(Y_t | Y^{t-1})$ (2.15)

c. independence

- $\sigma^2(X_t | X^{t-1}, Y^{t}) = \sigma^2(X_t | X^{t-1}, Y^{t-1}) = \sigma^2(X_t | X^{t-1})$ and

$\sigma^2(Y_t | X^{t}, Y^{t-1}) = \sigma^2(Y_t | X^{t-1}, Y^{t-1}) = \sigma^2(Y_t | Y^{t-1})$ (2.16)

3. EMPIRICAL RESULTS

For this study we used the annual number of registered cars and motorcycles and the GDP data. Our data on Taiwan was from the period 1952-2005 and that from Japan was from the period 1960-2003.

All variables were transformed as follows：

X：The natural logarithm of the GDP growth index using the year 2000 as the base period
Y：The natural logarithm of the number of registered motorcycles
Z：The natural logarithm of the number of registered cars

3.1 Empirical results in Taiwan

Figure 1 shows the growth of the number of registered motor vehicles in Taiwan. It shows that：

a. From 1971 to 1981, the number of registered motorcycles increased at an annual average rate of 19.6%. During this same period, although the number of registered cars is much less than the number of motorcycles, the increase in the annual average rate of cars was about 24.8%.
b. From 1981 to 1991, the growth rate of the number of registered motorcycles had dropped to about 5%, while the growth rate of cars was maintained at a significant level of about 18%.
c. From 1991 to 2001, further decreased to about 4.6%, while annual growth rate of registered motorcycles was reduced to about 6.6%.
d. After 2001, the growth rate of the number of registered motorcycles dropped even further to 3% , while the growth rate of the number of registered cars was down to about 3.4%.

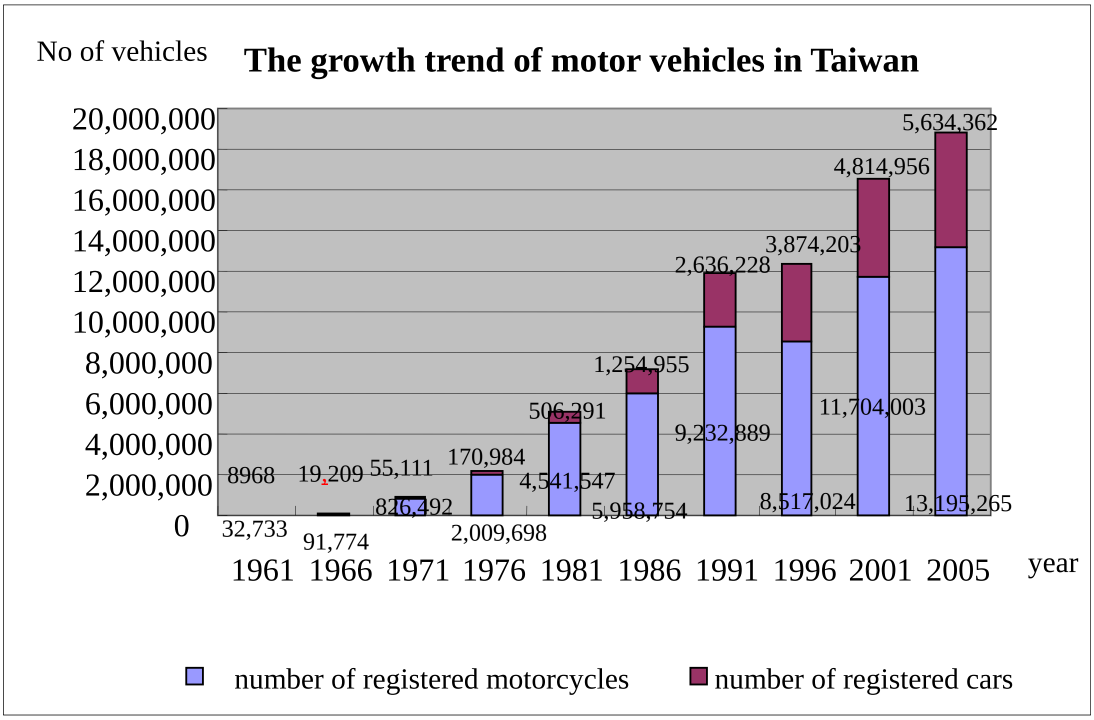

Figure 1 The growth trend of motor vehicles in Taiwan

3.1.1 Unit-root test

The results of the ADF test for the stationary properties of the variables in Taiwan are presented in Table 1.

The table shows that the τ statistics for all variables are greater than the critical values at the 1%, 5% and 10% levels from the ADF test, respectively. Thus, the results show that the null unit roots hypothesis cannot be rejected, thereby suggesting that all variables are non-stationary in their level forms. The results of the first differenced variables show that the ADF test statistics for all the variables were less than the critical value at the 5% and 10% level. Thus, all variables are stationary after differencing once, suggesting that all the variables are integrated of order I（1）.

Table 1 Results of the ADF test in Taiwan

	Ordinary series		First difference	
Variable	With constant	With constant and trend	With constant	With constant and trend
X(GDP)	-2.899849	1.620734	-4.351495*	-4.978701
Y(Motorcycle)	-2.90849	-0.761118	-4.569614*	-4.753599
Z(Car)	-2.090451	1.264194	-3.682767*	-4.324685
α	Critical value			
1%	-3.5572	-4.1383	-3.5598	-4.142
5%	-2.9167	-3.4952	-2.9178	-3.4969
10%	-2.5958	-3.1762	-2.5964	-3.1772

Note: X denotes the GDP; Y denotes the motorcycles; and Z denotes the cars.

3.1.2 Co-integration test

Before conducting the causality test between the GDP and the number of registered cars / motorcycles, it is necessary to conduct the co-integration test. This is necessary to avoid the problem of spurious regressions, although it may result in ignoring the long-run equilibrium relationship among variables if there is a co-integration relationship. The present study used the Johansen co-integration test.

Johansen’s co-integration test is based on the VAR（Vector auto-regression）model . The first step is to select the lag length. The appropriate lag lengths are two years, both between variable GDP(X) and variable Motorcycle(Y) and variable GDP(X) and variable Car(Z). The results of the co-integration test are presented in Tables 2 and 3. There is one co-integrated vector between variables X and Y and also one co-integrated vector between variables X and Z. This means that there are bidirectional relationships between them.

Table 2 Result of Johansen's co-integration test between Variable GDP(X) and Motorcycle(Y) in Taiwan

Eigen value	λ_{Trace}	critical value at 5% level	critical value at 1% level	Null hypothesis
0.371566	27.76494	19.96	24.6	$\gamma \le 0$
0.076778	4.074186	9.24	12.97	$\gamma \le 1$
	λ_{Max}	critical value at 5% level	critical value at 1% level	Hypothesis
	18.4151	15.67	20.2	$\gamma = 0$
	8.858564	9.24	12.97	$\gamma = 1$

Table 3 Result of Johansen's co-integration test between variables GDP(X) and CAR(Z) in Taiwan

Eigen value	λ_{Trace}	critical value at 5% level	critical value at 1% level	Null hypothesis
0.335388	21.49662	12.53	16.31	$\gamma \le 0$
0.012867	0.660459	3.84	6.51	$\gamma \le 1$
	λ_{Max}	critical value at 5% level	critical value at 1% level	Hypothesis
	20.83616	11.44	15.69	$\gamma = 0$
	0.660459	3.84	6.51	$\gamma = 1$

3.1.3 Error correction model

If there is a co-integrated relationship among the variables, then it is necessary to add one or more error correction values in order to establish an error correction model while adopting VAR. The value of the error correction represents the linear combination of the regression diverging from the long run equilibrium. The error correction model takes the error into consideration, and observes the dynamic adjustment behavior over the long-term. The results are expressed as the matrix：

$$\begin{bmatrix}\Delta x_t \\ \Delta y_t\end{bmatrix} = \begin{bmatrix}-0.0469 \\ -0.0389\end{bmatrix}\varepsilon_{t-1} + \begin{bmatrix}0.2012 & -0.0083 \\ 0.5467 & 0.5962\end{bmatrix}\begin{bmatrix}\Delta x_{t-1} \\ \Delta y_{t-1}\end{bmatrix} + \begin{bmatrix}-0.1515 & -0.0123 \\ 0.2139 & -0.3575\end{bmatrix}\begin{bmatrix}\Delta x_{t-2} \\ \Delta y_{t-2}\end{bmatrix}$$

Where the previous value of error $\varepsilon_{t-1} = (x_{t-1} - 0.3635 y_{t-1} - 11.1266)$

$$\begin{bmatrix}\Delta x_t \\ \Delta z_t\end{bmatrix} = \begin{bmatrix}0.0091 \\ -0.0123\end{bmatrix}\varepsilon_{t-1} + \begin{bmatrix}0.3139 & 0.0194 \\ 1.2866 & 0.2062\end{bmatrix}\begin{bmatrix}\Delta x_{t-1} \\ \Delta z_{t-1}\end{bmatrix} + \begin{bmatrix}-0.0840 & 0.0260 \\ 0.5618 & 0.2930\end{bmatrix}\begin{bmatrix}\Delta x_{t-2} \\ \Delta z_{t-2}\end{bmatrix}$$

Where the previous value of error $\varepsilon_{t-1} = (x_{t-1} - 0.7357 z_{t-1})$

3.1.4 Granger's causality test

In this section, we applied the Granger's causality test to discuss the relationship among variables. The traditional way to test causality is to establish the VAR model under the hypothesis that all variables are stationary. The causality can be determined by testing the coefficient of the lagged variable. However, if the variable is non-stationary, the result of the Granger's causality test will be questionable. Granger（1987） proposed the amendment to solve the problem. If two variables have a long-run relationship, it is necessary to add the error correction to the model to correct the result of the Granger's causality test when adopting the VAR model. The results are shown in Tables 4 and 5.

Table 4 Result of the Granger causality test between variables X(GDP) and Y(Motorcycle) in Taiwan

Null hypothesis	Number of observation	*F* statistic	*p-value*
X does not Granger-cause Y	52	0.4634	0.63198
Y does not Granger-cause X	52	4.18589	0.02123

Table 5 Result of the Granger causality test between variables X(GDP) and Z (CAR)in Taiwan

Null hypothesis	Number of observations	*F* statistic	*p-value*
Z does not Granger-cause X	52	0.20626	0.81435
X does not Granger-cause Z	52	8.22423	0.00087

The result of Granger's causality is based on the critical value of the *p-value* at α= 5%. From Table 4, the *p-value* of the null hypothesis "GDP(X) does not Granger-cause Motorcycle(Y)" （*p-value* = 0.63198）since is greater than 0.05, so the null hypothesis cannot be rejected. The *p-value* of the null hypothesis "Motorcycle(Y) does not Granger-cause GDP(X)" （*p-value* =0.02123）is less than 0.05, so the null hypothesis can be rejected. This means that there isn't any feedback between variables X and Y. Thus there is a unidirectional relationship "Motorcycle(Y) Granger-cause GDP(X)". That means that the growth of the number of motorcycle causes the GDP in Taiwan to increase. Table 5 shows that the growth of the GDP causes an increase in the use of cars in Taiwan.

3.2 Empirical results in Japan

Figure 2 shows the growth trend of motor vehicles in Japan, and it shows that：

a. From 1961 to 1971, the annual average growth rate of registered motorcycles was about 5.7%. During the same period, the annual average growth rate of cars was about 33%.

b. From 1972 to 1981, the annual average growth rate of motorcycles decreased to about 4.1% while the annual average growth rate of cars decreased to 8.9%.

c. After 1986, the number of registered motorcycle in Japan decreased by more than 5 million motorcycles from 18,668,554 to 13,369,000.

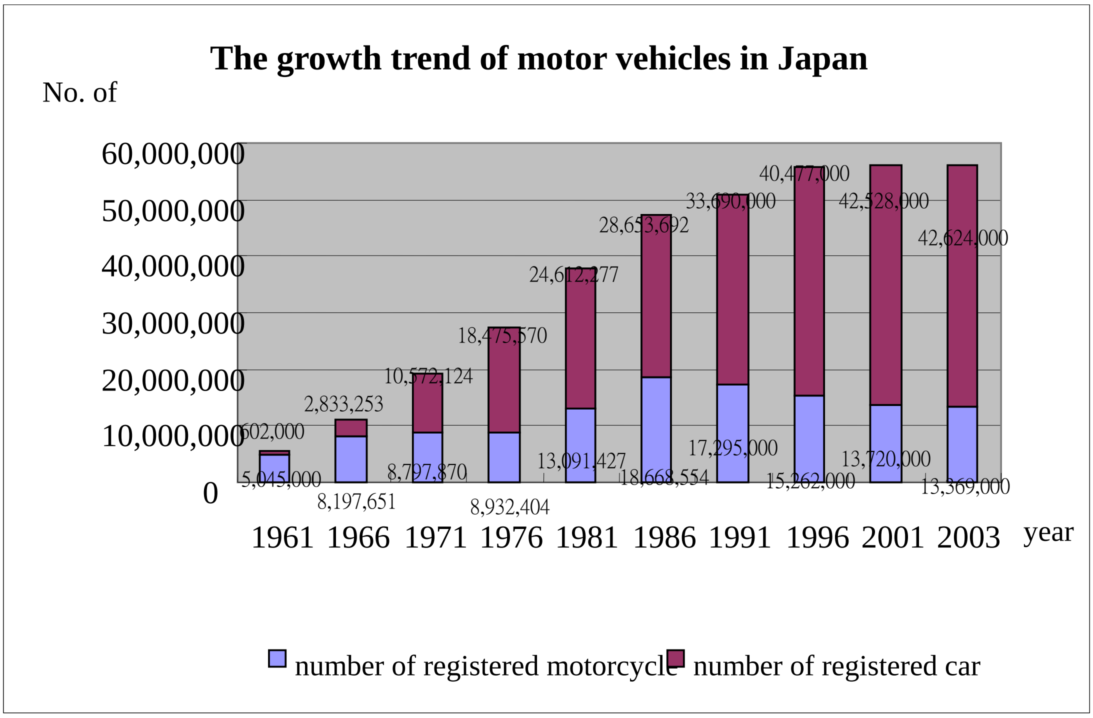

Figure 2 The growth trend of motor vehicles in Japan

3.2.1 Unit-root test

Table 6 shows the results of the ADF test for the stationary properties of the variables in Japan. It also shows that all variables are stationary under "with constant". Because variables X(GDP), Y(Motorcycle) and Z(Car) are all stationary series, it is not necessary to take the differentiation.

Table 6 Results of the ADF test in Japan

	Ordinary series	
Variable	With constant	With constant and trend
X (GDP)	-17.56643	-7.223174
Y (Motorcycle)	-5.063906	-1.665829
Z (Car)	-17.56643	-7.223174
α	Critical value	
1%	-3.593	-4.1896
5%	-2.932	-3.5189
10%	-2.6039	-3.1898

Note: X is variable GDP; Y is variable Motorcycle; Z is variable Car.

3.2.2 Granger's causality test

All variables are stationary without differencing, so the next step is to conduct Granger's causality test. The results are shown in Tables 7 and 8.

Table 7 Result of Granger's causality test between variables X(GDP) and Y(Motorcycle) in Japan

Null hypothesis	Number of observations	*F* statistic	*p-value*
X does not Granger-cause Y	41	3.16108	0.05435
Y does not Granger-cause X	41	5.03228	0.01183

Table 8 Result of the Granger causality test between variables X(GDP) and Z(Car) in Japan

Null hypothesis	Number of observations	*F* statistic	*p-value*
Z does not Granger-cause X	41	1.81553	0.17734
X does not Granger-cause Z	41	0.43769	0.64892

Using the *p-value*（at α= 5%）as a criterion, as shown in Table 7, the *p-value* of the null hypothesis "X does not Granger-cause Y", (*p-value* =0.05435） is greater than 0.05, the null hypothesis cannot be rejected. The *p-value* of the null hypothesis "Y does not Granger-cause X", （*p-value* = 0.01183）is less than 0.05, so the null hypothesis can be rejected. That means that there isn't any feedback between variables X and Y. Thus, in Japan it is the number of motorcycles that causes the GDP to grow and the GDP does not cause the number of motorcycles to grow. On the other hand, as shown in Table 8, the *p-value* of the null hypothesis "X does not Granger-cause Z"（*p-value* = 0.17734）is greater than 0.05, so the null hypothesis cannot be rejected. The *p-value* of the null hypothesis "Z does not Granger-cause X"（*p-value* = 0.64892）which is greater than 0.05 as well. This means that the relationship between variables GDP(X) and Car(Z) is independent.

4. CONCLUSION

This study applied the Granger's technique to test the relationship between the GDP and the number of motor vehicles. The ADF test, the co-integration test and Granger's causality test were conducted. The findings of the examination of the causal relationship between the GDP and the number of motor vehicles in Taiwan and Japan are as follows.

In Taiwan, the growth of the number of registered motorcycles causes the growth of the GDP. In Taiwan, the growth of the GDP causes the growth of the number of registered cars. There is a unidirectional causal relationship between the GDP and the number of registered cars and motorcycles. In Japan, the growth of the number of registered motorcycles causes the growth of the GDP, uni-directionally. In Japan there is no causal relationship between the growth in car ownership and the growth of the GDP. These findings indicate that in both Taiwan and Japan, motorcycle ownership will help economic growth. People in both Taiwan and Japan purchase a motorcycle before they can afford to buy a car .

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