AN ECONOMETRIC MODEL OF TAIWAN WITH POPULATION POLICY VARIABLES

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Introduction

In most previous attempts to construct econometric models of developing countries, population is treated as an exogenous variable which affects the economy in question but is not effected by it. That is, causality is usually assumed to operate in a single direction. This paper takes a somewhat different point of departure, namely that the economy of a country and the size of its population are jointly determined, and if one wants to understand the process of economic development he must attempt to delineate these relationships of mutual causality.

In this paper we describe a 24-equation econometric model of the economy of Taiwan which was estimated using two-stage least-squares on the basis of annual data for the period 1953-1968. Sixteen of the equations of the model are behavioral equations. The major sectors of the model include consumption, investment, foreign trade, production, monetary, labor force, and population. Unique to this model is the inclusion of equations explaining the birth rate and death rate for the economy of Taiwan. Of particular interest is the fact that the birth rate equation includes population policy variables. (Four alternative specifications of the birth rate equation are presented.) Computer simulation experiments for purposes of validation of the model are also included. Using the mean absolute percent error as a measure of goodness-of-fit for the simulations, the model is shown to yield extremely promising results over the data base period 1953-1968.

The variables and equations for the model are defined and specified in the following section.

TAIWAN MODEL: 1953-1968

Definition of Variables

Endogenous Variables

Birth = Live births per 1000

C = Consumption expenditure in millions of 1963 NT dollars

Curr = Currency in millions of NT dollars

DD = Demand deposits in millions of NT dollars

Death = Deaths per 1000

Exp = Exports in millions of 1963 NT dollars

I = Total investment in millions of 1963 NT dollars

I_{agr} = Investment in agriculture in millions of 1963 NT dollars

I_{ind} = Investment in industry in millions of 1963 NT dollars

I_{ser} = Investment in services in millions of 1963 NT dollars

Imp = Imports in millions of 1963 NT dollars

K_{agr} = Capital stock in agriculture in millions of 1963 NT dollars

K_{ind} = Capital stock in industry in millions of 1963 NT dollars

K_{ser} = Capital stock in services in millions of 1963 NT dollars

L_{agr} = Labor employed in agriculture in thousands

L_{ind} = Labor employed in industry in thousands

L_{ser} = Labor employed in services in thousands

$NNP_{\$}$ = Net national product in millions of NT dollars

NNP_{real} = Net national product in millions of 1963 NT dollars

P = Implicit price level, 1963=100

Pop = Population in thousands

Y_{agr} = Agricultural output in millions of 1963 NT dollars

Y_{ind} = Industrial output in millions of 1963 NT dollars

Y_{ser} = Services output in millions of 1963 NT dollars

Exogenous Variables

Inv = Changes in inventories in millions of 1963 NT dollars

IWT = Index of World Trade, 1963=100

Over 60 = Percent of population over age 60

Time = Time with 1953=1,...,1968=16

WPI/PTE = Ratio of World Price Index to price of Taiwan exports, 1963=100

Policy Variables

CMR = Crude marriage rate per 1000

*DVFP = Dummy variable for family planning program, equals zero from 1953 to 1963, one from 1964 to 1968

Policy Variables (continued)

Ex = Yearly expenditure of family planning per thousand population in constant 1963 NT dollars (1953-1963, Ex=0)

I_{govt} = Government investment in millions of 1963 NT dollars

Lit = Literacy rate in percent

*Loops = Yearly acceptances of interuterine devices per thousand population (1953-1963, Loops=0)

*Loops + Pills = Yearly acceptance of interuterine devices plus pill users

Q = Total money supply in millions of NT dollars

r = Interest rate, December of each year

Y_{govt} = Government output in millions of 1963 NT dollars

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*These can be policy variables if alternate Birth equations 15a, 15b, and 15c are used. See "Population: Alternative Birth Equations."

Behavioral Equations

Consumption

$$C = \underset{(48.90)}{.6965\ NNP_{real}} + \underset{(8.27)}{8325.2376} \quad (1)$$

$\bar{R}^2$ = .99, D.W. = 1.14

Investment

$$I_{agr} = \underset{(4.91)}{.0217\ NNP_{real}} + \underset{(2.65)}{.0455\ Y_{agr_{t-1}}} \quad (2)$$

$\bar{R}^2$ = .94, D.W. = 1.82

$$I_{ind} = \underset{(14.39)}{.1288\ NNP_{real_{-1}}} - \underset{(-4.17)}{745.4407\ r} \quad (3)$$

$\bar{R}^2$ = .89, D.W. = .45

$$I_{ser} = \underset{(14.66)}{.3009\ Y_{ser}} - \underset{(-4.6302)}{594.8094\ r} \quad (4)$$

$\bar{R}^2$ = .92, D.W. = 1.00

Note: In all equations, the values placed in parentheses below coefficients are t-statistics. $\bar{R}^2$ is the multiple correlation coefficient adjusted for degrees of freedom. D.W. is the Durbin-Watson statistic. Ln denotes the natural logarithm.

Foreign Trade

$$LnImp = \underset{(18.54)}{.9060\ LnI} + \underset{(2.35)}{.1373\ LnInv} \quad (5)$$

$\bar{R}^2$ = .99, D.W. = 2.36

$$LnExp = \underset{(200.00)}{2.0476\ LnIWT} + \underset{(2.96)}{.8804\ Ln\frac{WPI}{PTE}} \quad (6)$$

$\bar{R}^2$ = .96, D.W. = 1.66

Production

$$LnY_{agr} - LnK_{agr} = \underset{(19.78)}{.7662(LnL_{agr} - LnK_{agr})} + \underset{(21.33)}{1.7738} \quad (7)$$

$\bar{R}^2$ = .96, D.W. = .90

$$LnY_{ind} - LnK_{ind} = \underset{(20.44)}{.6558(LnL_{ind} - LnK_{ind})} + \underset{(16.71)}{2.2550} \quad (8)$$

$\bar{R}^2$ = .97, D.W. = .57

$$LnY_{ser} - LnK_{ser} = \underset{(19.47)}{.7692(LnL_{ser} - LnK_{ser})} + \underset{(18.55)}{2.4410} \quad (9)$$

$\bar{R}^2$ = .96, D.W. = .55

Monetary

$$DD = \underset{(26.67)}{.1150\ NNP_{\$}} - \underset{(-5.62)}{468.4520\ r} \quad (10)$$

$\bar{R}^2$ = .96, D.W. = .44

$$Curr = \underset{(40.02)}{.0646\ NNP_{\$}} \quad (11)$$

$\bar{R}^2$ = .97, D.W. = .38

Labor Force

$$L_{agr} = \underset{(131.12)}{.2158\ Pop} - \underset{(-28.38)}{53.7030\ Time} \quad (12)$$

$\bar{R}^2$ = .95, D.W. = .98

$$L_{ind} = \underset{(19.67)}{.0290\ Pop} + \underset{(5.12)}{8.6671\ Time} \quad (13)$$

$\bar{R}^2$ = .94, D.W. = .69

Labor Force (continued)

$$L_{ser} = \underset{(88.26)}{.0813}\ Pop \qquad (14)$$

$\bar{R}^2$ = .93 D.W. = .95

Population

$$Birth = \underset{(-4.111)}{-2.2659}\ Ex + \underset{(12.109)}{3.6305}\ CMR + \underset{(3.458)}{1.0866}\ Death_{-2} \qquad (15)$$

$\bar{R}^2$ = .95 D.W. = 1.20

$$Death = \underset{(-9.83)}{-.0013}\ NNP_{real}/POP - \underset{(-4.80)}{.1173}\ Lit + \underset{(15.51)}{547.1673}\ Over\ 60 \qquad (16)$$

$\bar{R}^2$ = .91 D.W. = 2.18

Population: Alternative Birth Equations

$$Birth = \underset{(2.71)}{.7702}\ Death_{-2} - \underset{(-5.74)}{4.0014}\ DVFP + \underset{(5.90)}{4.0220}\ CMR - .5734 \qquad (15a)$$

$\bar{R}^2$ = .97 D.W. = 1.75

$$Birth = \underset{(-4.985)}{-4.4717}\ Loops + \underset{(13.582)}{3.7818}\ CMR + \underset{(3.246)}{.94111}\ Death_{-2} \qquad (15b)$$

$\bar{R}^2$ = .96 D.W. = 1.48

$$Birth = \underset{(-4.957)}{-3.8519}\ (Loops+Pills) + \underset{(13.590)}{3.7601}\ CMR + \underset{(3.328)}{.96062}\ Death_{-2} \qquad (15c)$$

$\bar{R}^2$ = .96 D.W. = 1.32

Identities

$$I \equiv I_{agr}+I_{ind}+I_{ser}+I_{govt} \qquad (17)$$

$$K_{agr} \equiv K_{agr_{-1}} + I_{agr} \qquad (18)$$

$$K_{ind} \equiv K_{ind_{-1}} + I_{ind} \qquad (19)$$

$$K_{ser} \equiv K_{ser_{-1}} + I_{ser} \qquad (20)$$

$$NNP_{real} \equiv Y_{agr}+Y_{ind}+Y_{ser}+Y_{govt} \qquad (21)$$

$$P \equiv NNP_{\$}/NNP_{real} \qquad (22)$$

$$Pop \equiv Pop_{-1}(1+Birth/1000-Death/1000) \qquad (23)$$

$$Q \equiv DD + Curr \qquad (24)$$

Description of the Model

Consumption

The consumption equation (1) relates total consumption to the real net national product. Real net national product was used rather than disposable income because of the unavailability of a suitable data series for disposable income or the component series necessary to compute disposable income from net national product. The decision to use net national product was based on the assumption that it was probably a more appropriate proxy for disposable income than any other variable for which data were available.

The annual marginal propensity to consume was found to be approximately .70 which is in the expected range for Taiwan.

Investment

Investment was disaggregated into the agricultural, industrial, and service sectors. Agricultural investment (2) was found to be related to current net national product and the net national product of the agricultural sector in the preceding year. Earlier regressions indicated that agricultural investment was not significantly related to the interest rate. This specification appears to be tenable, especially considering the lack of modern credit facilities serving the agricultural sector in Taiwan.

Investment in both the service sector (3) and the industrial sector (4) was found to be related to the current output of that sector and to the supply price of capital--that is, the long-term interest rate. The aggregation of such capital intensive industries as the electric industry and the transportation industry under the service sector represents an argument for the observed relationship between service investment and the long-term interest rate.

Foreign Trade

Both the export and import equations were estimated in their log-linear forms, as is frequently the practice. In the export equation (6), the Index of World Trade is used as a proxy for the rest of the world's demand for Taiwan's

produce. Exports were also found to be related to the prices of Taiwan's export commodities relative to the prices of goods traded in world markets. We expect a positive sign on the ratio of the World Price Index to an index of the price of Taiwan's exports; as world prices rise relative to Taiwan's prices, Taiwan's exports become relatively more attractive. The coefficient of WPI/PTE, .88, is an elasticity--the elasticity of demand for Taiwan's exports with respect to the price ratio (WPI/PTE). The obtained value is in the expected range. Imports (5) were found to be related to two measures of investment demand, fixed capital formation (I) and additions to inventory (Inv). This is a reflection of the fact that a very large and growing portion of Taiwan's imports are used for investment. (The situation is slightly changed after 1970; imports of consumer goods have been increasing steadily as the government eases up on the permits for consumer goods imports.)

Production

The three equations describing sector outputs--(7), (8), and (9)--all assume the familiar form of linearly homogeneous Cobb-Douglas functions. They possess the theoretically attractive properties of constant returns to scale, positive first partials, and negative second partials. Other specifications such as quadratic functions or homogeneity of some degree other than zero were tried, but in all cases they yielded significantly worse results.

A note of explanation is necessary for the capital series that we employed for each of the three sectors. The only available breakdown by sectors gave annual current price investment figures. We converted these to a real series by applying appropriate sector deflators to agriculture and industry and applying the Consumer Price Index to the service sector. The real investment figures were then summed from 1951 to time t, yielding sector capital for t=1953 to t=1968. Some bias will clearly result for early years where sector capital stock is underestimated, but it is probably quickly dominated by rapidly rising investment expenditures that began to occur in the mid-fifties as Taiwan's rate of development increased. Because of the fact that investment rose rapidly and out of fear of introducing further bias, no attempts were made to extrapolate the investment figures backwards or correct the early years capital figures.

Monetary Sector

Equations (10) and (11) and identity (24) comprise the monetary sector of the model. They provide the three endogenous variables--demand deposits, currency, and nominal NNP. These variables are influenced by the exogenous interest rate and the total money supply.

In its present specification we have essentially a simple quantity theory that is reminiscent of the "classical" macroeconomics. Increases in the money supply affect prices via equations (24), (11), and (22). However, the real sector of the model is unchanged by such increases or decreases.

Equation (10) estimates the quantity of demand deposits as a function of nominal NNP and the interest rate. A higher nominal NNP requires a higher level of deposits, but since the interest rate acts as a "price" for demand deposits, we find the expected negative sign on r. Changes in the interest rate will affect not only demand deposits, but also investment in the industrial and service sectors.

Labor Force

The three "supply of labor" equations (12), (13), and (14) relate total population to the labor force in the three sectors. At first we attempted some conventional labor supply equations based on wage rates and wage shares. In many cases the signs of the coefficients were wrong, and often significantly so. Wages were then abandoned in favor of the simple population and time trend arguments that appear in the equations. This produced satisfactory prediction in all cases and even yielded significant evidence of a time trend movement of workers out of agricultural employment and into the industrial sector. This is logically consistent with the country's attempts to develop industrially. (Further, during the period 1953-1968 there was no significant time trend in the labor equation for the service sector.)

Demographic Sector

The demographic sector consists of two behavioral equations--one estimating the crude birth rate (15) and the other the crude death rate (16)--and an identity (23) for calculating total population. Crude birth rates and death rates were used rather than age-specific or standardized rates to avoid unnecessary complications in the specification of the equations.

The birth rate equation (15) relates the crude birth rate to the death rate lagged two periods and the crude marriage rate. Perhaps the most interesting aspect of the birth rate equation is the inclusion of a population policy variable, Ex, which reflects annual expenditures for family planning per thousand population for the years 1964 through 1968. This variable takes on a value of zero over the period 1953 through 1963 since

the Taiwan family planning program was not inaugurated until 1964. The three alternative specifications of the birth rate equation are also included--equations (15a), (15b), and (15c). Each of these equations includes the death rate lagged two periods and the crude marriage rate as explanatory variables. In equation (15a) the effects of the national family planning program are reflected through the use of a dummy variable which takes on the value of zero for the years 1953 through 1963, when Taiwan had no family planning program, and the value 1 for the period 1964 through 1968--the period in which Taiwan did have a family planning program. Equation (15b) follows a slightly different specification in terms of the population policy variable. In this case the annual acceptance rate of inter-uterine devices per thousand population was used as the policy variable. Finally, in equation (15c) the yearly acceptance rate of inter-uterine devices plus pill users was the policy variable. In each specification of the birth rate equation, the population policy variable was clearly significant at the .01 level, indicating that Taiwan's family planning program had indeed led to a reduction in the birth rate in Taiwan.

The specification of the birth rate equation draws heavily on the recent work of T. Paul Schultz, who has successfully explained the changes in fertility in a number of developing countries [2]. Schultz has formulated an econometric model which attempts to explain the frequency of births in a population in terms of three groups of factors that influence parents' desires for births: (1) the family size goal or number of surviving children that parents want; (2) the incidence of death, mainly among offspring, which necessitates an adjustment in birth rates to achieve any given family size goal; (3) the effect of uncertainty in the family formation process where births, deaths, and remarriage are unpredictable.

The death rate equation (16) contains environmental variables--average income and the literacy rate--and a third variable whose effect is simply that of compensating for the effect of a changing age structure on the crude death rate. Several attempts to identify one or more variables representing measures of the availability of medical personnel or health care delivery services were found to have insignificant effects on the death rate. Neither registered medical personnel per thousand population nor health delivery facilities per thousand population were found to have coefficients which were significantly different from zero.

On the other hand, average income may be assumed to represent a type of measure of social well-being, and the literacy rate may represent a measure of the accessability to modern health information.

The third variable--percent of total population over sixty--represents an attempt to come up with a crude proxy for the age structure of the population of Taiwan. As the mortality rate in younger age groups declined rapidly, with the decline of the birth rate lagging behind, Taiwan's population became much younger. Therefore, part of the decline in the crude birth rate is attributable to the lowering of the average age of the population along with the lower age-specific mortality rates in younger age groups. This may be a transitory phenomenon; as both the birth rate and death rate continue to fall, the population will again have an older age structure which will cause an increase in the death rate, ceteris paribus.

Computer Simulations

A severe test of the validity of a large-scale econometric model is how well does the model predict the behavior of the observed values of the system when the model is treated as a closed-loop simulation. To validate a model of Taiwan, we have repeatedly solved the model for the endogenous variables of the system in terms of the exogenous variables, policy variables, and lagged endogenous variables. The values of the lagged endogenous variables are those generated by the model in the preceding period, thus making the simulation a completely closed-loop procedure.

Since the model contains several non-linear equations, it was necessary to use the Gauss-Seidel method to solve the system of simultaneous non-linear difference equations. Since space limitations do not permit giving complete simulation results, a table of the mean absolute percentage error for eleven of the more important variables is given below.

In future experiments with the model we expect to experiment with the effects of alternative population, monetary, and fiscal policies on the behavior of the Taiwan economy.

Table 1

Simulation Results

Variable	Mean Absolute Percentage Error
Birth Rate	2.3
Death Rate	8.3
Population	1.1
NNP (real)	7.3
Consumption	5.2
Imports	17.4
Investment	17.8
Currency	8.7
Demand Deposits	9.2
NNP (nominal)	7.1
Price Level	13.1

Data Sources

Bank of Taiwan
Central Bank of China
Government Bureau of Audit and Statistics
Ministry of Communication
Ministry of Economic Affairs
Ministry of Finance
Population Registration Statistics of Taiwan (monthly bulletin)
Provincial Department of Commerce
Report of Taiwan Labour Statistics
Taiwan Customs
Taiwan Demographic Fact Book (annual publication)
Taiwan Power Company

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