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DEMAND SYSTEM ANALYSIS FOR MONETARY ASSETS IN AUSTRALIA

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Abstract. *In this paper, almost ideal demand system (AIDS) and linearized almost ideal demand system (LAIDS) are employed to estimate the demand for monetary assets and provide some empirical evidences about the substitutability between financial assets in Australia. These two models are reported to have serial correlation problems and both the values of R^2 and D-W statistics are exhibited improvements after taking serial correlation into account. The empirical results of elasticity reveal the weak substitutability between monetary assets examined in this estimation. The demand for monetary assets shows more complexity. The results vary dramatically through various models. AIDS is a better fit model than LAIDS model after empirical comparison. AIDS is a reliable measure on the estimation of elasticity.*
Keywords: Demand system, AIDS, LAIDS, Monetary assets

1. **Introduction.** Since the mid-1970s, Australian economic policy has been driven by the idea that minimal government regulation will promote economic growth [1]. This paper aims to measure the demand for monetary assets and discover the impacts from certain variables such as deregulation in the 1980s on the substitutability between monetary assets.

The issue of the substitutability of monetary assets has attracted many economists to investigate financial models that are fit for monetary demand. The translog indirect utility function is used by Drake [2] to examine the demand for various capital certain, liquid financial assets in the U.K. They applied Divisia quantity and rental index for building society shares and deposits, and found that the use of Divisia procedures to aggregate across financial products is an alternative. In the research of Ramachandran and Kamaiah [3], the own-price elasticity results are reported to be inconsistent with demand theory. Davis and Gauger [4] propose net M2 and net M3 assets are sometimes regarded as 'luxury goods' assets and thus should show large responses to expanding income.

Jadidzadeh and Serletis [5] use a highly disaggregated demand system to estimate the degree of substitutability among monetary assets and to address the issue of optimal monetary aggregation in the United States. They believed the broadest M4 monetary aggregate published by the Center for financial stability should be employed.

However, according to Jin [6], the theoretical regularity conditions were imposed in normalized quadratic function, Morishima elasticities of substitution among currency, demand deposits and time deposits were estimated, the results were found that the narrow money M1 is well-defined, while the broad money M2 is problematic.

To find out the property of monetary assets and the substitutability between them, this paper would use AIDS (almost ideal demand system) and linearized AIDS to do the estimation. Specific models would be interpreted in the second part, data would be

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described in the third part, and the following would be main results of the estimation. Finally, a conclusion would be given based on the empirical results.

2. Specification of the Models.

2.1. Specification of AIDS and linearized AIDS models. The AIDS model stems from a specific class of preferences, which is known as the price independent generalized logarithmic (PIGLOG) expenditure function form introduced by Deaton and Muellbauer [7]:

$$\log Y^C(p,u) = \log(P1) + u * P2 \tag{1}$$

where the superscript C means compensated expenditure function at certain level of utility, Y is the amount of income used to allocate among n number of monetary assets, Ω_+^{N1} is the strictly positive orthant, $p \in \Omega_+^{N1}$ represents the rental cost corresponding to monetary assets, u is the level of utility, PIGLOG expenditure function defines the minimum cost to maintain the given level of utility. $P1$ is specified as a homogenous of degree one (HD1) Translog function in a vector of prices, p, and $P2$ is a homogenous of degree zero (HD0) Cobb-Douglas function in a vector of p. The specific functional forms are as follows:

$$P1 = \exp\left(\sum_{i=1}^{N} \alpha_i \ln p_j + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \gamma_{ij} \ln p_i \ln p_j\right) \tag{2}$$

$$P2 = \prod_{j=1}^{N} p_j^{\beta_j} \tag{3}$$

where α_i, β_j and γ_{ij} are coefficients that need to be estimated. A PIGLOG expenditure function has to satisfy the properties of adding up, symmetry and homogeneity, that is

$$\sum_{i=1}^{N} \alpha_j = 1 \tag{4}$$

$$\sum_{j=1}^{N} \beta_j = 0 \tag{5}$$

$$\sum_{i=1}^{N} \gamma_{ij} = 0, \quad \gamma_{ij} = \gamma_{ji}\ (i \neq j) \tag{6}$$

It is noted that the price of each monetary asset is the "rental cost", which is interpreted by Donovan [8] as the relevant prices of the service flows yielded by the monetary assets. The formula is expressed as

$$p_i = \frac{\pi(r^* - r_i)}{1 + r^*} \tag{7}$$

where π represents the consumer price index, r^* is the benchmark interest rate, and r_i is the interest rate of the ith monetary asset.

Applying Shepherd's lemma to Equation (1), budget share function can be obtained:

$$W_i = \frac{p_i m_i}{\sum_{i=1}^{N} p_i m_i} = \frac{p_i m_i}{Y} \tag{8}$$

$$W_i^C = \frac{\partial \log Y^C(p,u)}{\partial \log p_i} = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_j u \prod_{j=1}^{N} p_j^{\beta_j} \tag{9}$$

where W_i^C is the compensated budget share, p_i is the rental cost of the ith monetary asset, and m_i is the demand of the ith asset. To estimate the budget share, uncompensated AIDS budget share has to be derived. By inverting PIGLOG expenditure function, uncompensated utility function is given:

$$U^{UC}(p, y) = \frac{\ln(Y/P1)}{P2} \tag{10}$$

Applying Roy's identity, uncompensated budget share function can be obtained:

$$\frac{-\partial U^{UC}/\partial \log(p_i)}{\partial U^{UC}/\partial \log(Y)} = W_i^{UC}(p, Y) \tag{11}$$

Substituting Equation (10) into Equation (9) results in the corresponding non-linear uncompensated budget share system:

$$W_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_j R \tag{12}$$

where $R = \ln\left(\frac{y}{P1}\right)$, y is the total income used to allocate among n number of monetary assets, the estimation becomes much more easier if R is linear. Deaton and Muellbauer [7] noticed it and adopted Stone's price index, which can be expressed as

$$\log P1 \approx \log P1^* = \sum_{i=1}^{N} w_i p_i \tag{13}$$

Substituting Equation (13) into Equation (12), then the linearized AIDS (LAIDS) is as follows:

$$W_i^C = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_j \ln\left(\frac{y}{P1^*}\right) \tag{14}$$

2.2. **AIDS and LAIDS elasticities.** The specific functional form makes it possible to estimate the elasticities of both AIDS and LAIDS model. Income elasticity is the percentage change in demand of ith asset response to percentage change in individual income. m_i^{UC} represents the demand of the ith monetary asset, and Y is income of households that is used to allocate n number of monetary assets. The definition of income elasticity is as follows:

$$E_i = \frac{\partial \log m_i^{UC}}{\partial \log Y} \tag{15}$$

Taking log of Equation (8), $\log m_i^{UC}$ can be derived as

$$\log w_i^{UC} = \log p_i + \log m_i^{UC} - \log Y \tag{16}$$

$$\log m_i^{UC} = \log w_i^{UC} - \log p_i + \log Y \tag{17}$$

Differentiating on both sides on Equation (17), uncompensated income elasticity can be obtained:

$$E_i = \frac{\partial \log m_i^{UC}}{\partial \log Y} = \frac{\partial \log w_i^{UC}}{\partial \log Y} + 1 \tag{18}$$

Price elasticity can be derived similarly:

$$\frac{\partial \log m_i^{UC}}{\partial \log p_j} = \frac{\partial \log w_i^{UC}}{\partial \log p_j} - \frac{\partial \log p_i}{\partial \log p_j} = \frac{\partial w_i^{UC}}{\partial \log p_j} * \frac{1}{w_i^{UC}} - \delta_{ij} \tag{19}$$

$$\delta_{ij} = \frac{\partial \log p_i}{\partial \log p_j} = \begin{cases} 1 & i \neq j \\ 0 & i = j \end{cases} \tag{20}$$

Uncompensated income elasticity and price elasticity may be estimated using the below equations.

Uncompensated Income Elasticity

$$E_i = 1 + \left(\frac{\beta_i}{w_i}\right) \tag{21}$$

Uncompensated Price Elasticity

$$M_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left(\alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j\right) \tag{22}$$

3. Data Description.

3.1. **Data sources.** This empirical estimation uses annual time series data spanning the period 1970-2020. The data of interest rate, monetary assets and consumer price index (CPI) is obtained from Reserve Bank of Australia, unemployment rate and female participation rate which serve as additional quantitative variables are from Australian Bureau of Statistics (ABS). Considering the deregulation in the 1980s, a dummy variable is added in the model to find out the influence of government policy to monetary demand.

Four financial assets are selected to estimate the money demand, which are

M1 – Currency of the private non-bank sector.
M2 – Current bank deposits of the private non-bank sector.
M3 – Term deposits of the private non-bank sector.
M4 – Other borrowings from private sector by AFIs.

3.2. **Model specification.** The empirical estimation in this paper, additional variables are included to test whether these factors are significant and thus pose impacts on the monetary demand. As is interpreted before, one dummy variable enters in the budget share system to test the influence of deregulation in the 1980s, and time trend is also considered as an impact of technological improvement in the long term. Following the suggestion of Cooper and McLaren [19], two quantitative variables, unemployment rate and female participation rate, are included.

After the variables are included in the model, the empirical model are as follows:

Almost Ideal Demand System (AIDS):

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{y}{P1}\right) + \varphi_{ui} u + \varphi_{fi} f + \psi_{(1)i} t + \psi_{(2)i} t^2 + \delta_i d + \mu_i$$

$$\text{where } \ln(P1) = \sum_{i=1}^{N} \alpha_i \ln p_j + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \gamma_{ij} \ln p_i \ln p_j \tag{23}$$

Linearized Almost Ideal Demand System (LAIDS):

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{y}{P1^*}\right) + \varphi_{ui} u + \varphi_{fi} f + \psi_{(1)i} t + \psi_{(2)i} t^2 + \delta_i d + \varepsilon_i$$

$$\text{where } \log P1^* = \sum_{i=1}^{N} w_i p_i \tag{24}$$

where u is the unemployment rate, f is the female participation rate, t is the time trend, d is the dummy variable, φ_{ui}, φ_{fi}, $\psi_{(1)i}$, $\psi_{(2)i}$, and δ_i are parameters, and ε_i, and μ_i are error terms.

4. Empirical Results.

The empirical approach of demand system is applied to estimating demand and the substitutability of financial assets.

4.1. **Empirical results without serial correlation control.** AIDS and LAIDS are used in this paper for comparison. One equation has to be deleted in order to avoid singular matrix. The equation of AFIs, which shares least in the expenditure, is deleted for the estimation. Estimation has been carried out using the LSQ option of the Time Series Processor (TSP) 5.0 computer package.

Table 1. Empirical results for AIDS

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{y}{P1}\right) + \varphi_{ui} u + \varphi_{fi} f + \psi_{(1)i} t + \psi_{(2)i} t^2 + \delta_i d + \mu_i$$

Parameters

α_1	0.5762 $(-4.12526)^{***}$	γ_{44}	-0.2416 $(-10.6827)^{***}$	$\psi_{(1)1}$	0.0002 (-0.04464)
α_2	1.2702 $(10.5497)^{***}$	β_1	-0.9784 $(-5.23418)^{***}$	$\psi_{(1)2}$	0.0158 $(4.15824)^{***}$
α_3	0.8383 $(5.80091)^{***}$	β_2	-0.0774 $(-5.89607)^{***}$	$\psi_{(1)3}$	0.0071 (-1.68637)
α_4	-1.6847 $(-11.0369)^{***}$	β_3	-0.0728 $(-4.17092)^{***}$	$\psi_{(1)4}$	-0.0144 $(-2.10514)^{**}$
γ_{11}	0.1614 $(8.72047)^{***}$	β_4	0.2481 $(16.6227)^{***}$	$\psi_{(2)1}$	0.0001 (-1.04478)
γ_{12}	-0.1575 $(-16.1095)^{***}$	φ_{u1}	0.1287 $(3.53469)^{***}$	$\psi_{(2)2}$	-0.0001 (-1.16554)
γ_{13}	-0.0966 $(-11.6518)^{***}$	φ_{u2}	-0.0135 (-0.00367366)	$\psi_{(2)3}$	0.0001 (-0.89523)
γ_{14}	0.0927 $(4.29859)^{***}$	φ_{u3}	0.0036 (-0.842643)	$\psi_{(2)4}$	-0.0002 (-1.49082)
γ_{22}	0.1830 $(9.86963)^{***}$	φ_{u4}	-0.0067 (-1.10254)	δ_1	-0.0024 (-0.95244)
γ_{23}	-0.0924 $(-6.81355)^{***}$	φ_{f1}	0.0083 $(3.09031)^{***}$	δ_2	-0.0100 (-0.482988)
γ_{24}	0.0669 $(4.03783)^{***}$	φ_{f2}	-0.0049 $(-1.76411)^{*}$	δ_3	0.0013 (-0.06282)
γ_{33}	0.1070 $(7.62909)^{***}$	φ_{f3}	0.0033 (-1.14628)	δ_4	0.0231 (-0.6604)
γ_{34}	0.0820 $(3.37645)^{***}$	φ_{f4}	-0.0118 (-1.5297)		

	R^2	D-W statistics
w_1: Currency	0.9553	1.8185
w_2: Current Deposits	0.9664	1.1354
w_3: Term Deposits	0.8735	1.0509
w_4: AFIs Deposits	0.9564	2.1036

Notes:

1) category1 = currency, category2 = current deposits, category3 = term deposits, category4 = other borrowings from private sector by AFIs.

2) *: the value is statistically significant at 90% level.

3) **: the value is statistically significant at 95% level.

4) ***: the value is statistically significant at 99% level.

All of the parameters are very significant except for macro variables. The R^2 values range from 87 per cent to 96 per cent, which confirms the goodness of fit. R^2 values of current deposits is the highest, while term deposits reported the lowest. This result may indicate that the share of term deposits may not be completely explained by basic AIDS model.

The results of D-W statistics are disappointing when focusing on current deposits and term deposits, which are reported 1.13 and 1.05 respectively. Low D-W statistics may be caused by serial correlation in the residuals.

In AIDS model, β_i measures the impact of change in real expenditure on budget share. Positive sign of this parameter indicates luxury assets, while negative represents necessity assets. Only AFIs deposits is shown to be a luxury asset with strong significance.

Macro variables in this model are not very statistically significant except for currency. Unemployment rate has a positive effect on the holdings of currency, which is in accordance with the fact that currency is necessity asset. When female participation rate increases, people are inclined to keep more currency. Two out of eight time trends are significant. None of the dummy variable is significant. It indicates a negative effect on currency and current deposits, while positive on term deposits and AFIs deposits.

TABLE 2. Empirical results for LAIDS

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{y}{P1^*}\right) + \varphi_{ui} u + \varphi_{fi} f + \psi_{(1)i} t + \psi_{(2)i} t^2 + \delta_i d + \varepsilon_i$$

Parameters

α_1	2.2121 (8.98852)***	γ_{44}	0.0336 (2.05211)**	$\psi_{(1)1}$	0.0296 (7.01101)***
α_2	0.6429 (2.2352)**	β_1	−0.2587 (−10.1366)***	$\psi_{(1)2}$	0.0140 (1.75312)*
α_3	−0.7163 (−1.74661)*	β_2	0.0358 (−1.48593)	$\psi_{(1)3}$	−0.0166 (−2.13997)**
α_4	−1.1386 (−2.13911)**	β_3	0.0310 (−0.90669)	$\psi_{(1)4}$	−0.0322 (−1.96262)*
γ_{11}	0.1289 (18.9612)***	β_4	0.1919 (4.81772)***	$\psi_{(2)1}$	−0.0002 (−4.83059)***
γ_{12}	−0.1074 (−14.1363)***	φ_{u1}	0.0079 (2.69726)**	$\psi_{(2)2}$	−0.0001 (−1.18951)
γ_{13}	−0.0314 (−3.99207)***	φ_{u2}	−0.0202 (−4.59667)***	$\psi_{(2)3}$	0.0002 (2.96506)***
γ_{14}	0.0099 (2.60006)**	φ_{u3}	0.0087 (2.24361)**	$\psi_{(2)4}$	0.0001 (−0.741807)
γ_{22}	0.2402 (16.1878)***	φ_{u4}	0.0006 (−0.064571)	δ_1	0.0118 (−0.740984)
γ_{23}	−0.0982 (−12.1223)***	φ_{f1}	0.0076 (2.29744)**	δ_2	−0.0556 (−2.26014)**
γ_{24}	−0.0345 (−3.9744)***	φ_{f2}	−0.0163 (−3.65155)***	δ_3	−0.0332 (−1.15362)*
γ_{33}	0.1386 (19.4011)***	φ_{f3}	0.0179 (3.17307)***	δ_4	−0.0003 (−0.00478289)
γ_{34}	−0.0090 (−1.01207)	φ_{f4}	−0.0229 (−1.74606)*		

	R^2	D-W statistics
w_1: Currency	0.9722	1.3549
w_2: Current Deposits	0.9315	1.0225
w_3: Term Deposits	0.9003	1.3530
w_4: AFIs Deposits	0.8647	1.3427

Notes:

1) category1 = currency, category2 = current deposits, category3 = term deposits, category4 = other borrowings from private sector by AFIs.

2) *: the value is statistically significant at 90% level.

3) **: the value is statistically significant at 95% level.

4) ***: the value is statistically significant at 99% level.

A comparison of parameters with AIDS model indicates that LAIDS may not be suitable for the estimation of monetary assets. Although the highest R^2 values increase to 97 per cent, the range of R^2 values become large, from 86 percent to 97 percent, with relatively low D-W statistics. The real expenditure coefficients of current deposits and term deposits are not significant. Note that significant and positive signs of AFIs indicate AFIs a luxury asset, which is consistent with rationale.

Most of the macro variables are statistically significant, unemployment rate has a positive effect on currency and term deposits, a negative effect on current deposits is reported significantly.

Six out of eight time trends and two out of four dummy variable coefficients are statistically significant. Dummy variable shows that deregulation has a negative impact on current deposits and term deposits. Although the sign of dummy variable indicated a negative effect on AFIs, which is expected for deregulation, it still fails to make any sense because of low magnitude and insignificance.

4.2. **Elasticity and elasticity of substitution.** Estimates of income elasticity, uncompensated own-price elasticity, uncompensated cross-price elasticity, compensated price elasticity are used for common goods. To analyze the substitutions among monetary assets, some specific indices like Allen elasticity of substitution (AES), Morshima elasticity of substitution, Mundlak elasticity of substitution are applied in this paper.

Income Elasticity

The estimated income elasticity in the AIDS indicate that currency, current deposits and term deposits are 'normal goods', AFIs deposits are shown to be 'luxury goods', which means that people are inclined to hold more AFIs deposits when income increases. The negative signs of the estimates appeared in the LAIDS may suggest this model is not fit compared with AIDS.

Price Elasticity.

The estimated own-price elasticities for both uncompensated and compensated report to be positive in the AIDS, this disappointing result is not consistent with demand theory; which may be explained by the uncertainty of deregulation in the 1980s. To avoid risk, more assets are required when prices are increasing. Almost half of cross-price elasticities are negative in AIDS and LAIDS, which suggest the weak substitutability between assets. The positive sign of the elasticities between AFIs and the other three monetary goods in the AIDS and LAIDS indicates that AFIs deposits are substitutes for the other assets.

Elasticity of Substitution.

The estimated Allen elasticity of substitution (AES) indicates that all the own elasticities of substitution are positive in all three models, which suggest the necessary curvature conditions are not satisfied at the point of approximation. Note that the demand responses to rental price changes are not symmetric between all monetary assets. Morishima elasticity of substitution (MES) and Mundlak elasticity of substitution (UES) are described as better proxies. One surprising result is that when MES and UES are used, some findings of substitutes estimated in AES reserved to be complements, which is consistent with the findings from Davis and Gauger [4].

Similar results are shown when serial correlation is imposed. The existence of serial correlation has not much to do with the estimation of elasticities.

5. **Concluding Remarks.** In this paper, almost ideal demand system and linearized almost ideal demand system are employed to estimate the demand for monetary assets and provide some empirical evidences about the substitutability between financial assets in Australia.

Among monetary assets, only AFIs deposits are shown to be luxury goods, the relatively high values of elasticity also confirm this point. The impact of macro variables may not be so obvious, a slight negative relation is found between unemployment rate and currency demand, which indicates the fact that people are willing to hold more necessity financial goods when facing the possibility of being unemployed. Not much explicit evidence is captured for the influence of female participation rate. Another disappointing result is that time trend fails to have strong impacts in the systems. Dummy variables do have impacts on money demand, which is not surprising and justifies the sufficient evidence for the inclusion of deregulation in the 1980s.

The finding of positive signs of own-price elasticity is opposite to demand theory, which cast doubt of the fit of the models. The estimated elasticities reveal the weak substitutability between monetary assets examined in this estimation. They are somewhat complements to some extent, which argues the simple sum procedure for constructing the monetary aggregates.

The demand for monetary assets shows more complexity. The results vary dramatically through various models. AIDS is a better fit model after empirical comparison, and AIDS is still a reliable measure on the estimation of elasticity. This study could be extended by using intertemporal demand system analysis instead of static analysis, provided that the monthly and quarterly data are available. Intertemporal analysis is expected to be better for capturing intertemporal demand behavior.

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