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A STRUCTURAL ANALYSIS OF MONEY DEMAND: CROSS-SECTIONAL EVIDENCE FROM JAPAN

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ABSTRACT

Following the study of U.S. regional data by Mulligan and Sala-i-Martin (1992) and Fujiki and Mulligan's (1995) discussion of empirical models of the demand for money, we use Japanese prefecture data to estimate the parameters of a money demand function. Our cross sectional estimates of the income elasticity for a counterpart of M2 minus cash are in the range 1.2-1.4 and appear to be stable over time. We use the cross sectional income elasticities to estimate the interest rate elasticity of money demand from the macro time series data, and to assess changes over time in the degree of financial sophistication.

KEY WORDS: Demand for Money, Monetary Policy

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Abstract

Following the study of U.S. regional data by Mulligan and Sala-i-Martin (1992) and Fujiki and Mulligan's (1995) discussion of empirical models of the demand for money, we use Japanese prefecture data to estimate the parameters of a money demand function. Our cross sectional estimates of the income elasticity for a counterpart of M2 minus cash are in the range 1.2-1.4 and appear to be stable over time. We use the cross sectional income elasticities to estimate the interest rate elasticity of money demand from the macro time series data, and to assess changes over time in the degree of financial sophistication.

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1. Introduction

We suppose that monetary phenomena are determined by three sets of variables: (1) parameters of agents' utility or production functions, (2) technological constraints, and (3) monetary policy. We show how relationships between the money stock, GNP, and other variables depend on (1), (2) and (3) and how parameters of agents' utility or production functions can be estimated from aggregate data.

Following Mulligan and Sala-i-Martin (1992), we note that estimation of structural parameters from aggregate data requires several identifying restrictions, but that those restrictions are more plausible in a cross-region analysis than in an aggregate time series analysis. We see at least three advantages to estimate money demand function from cross sectional data. First, interest rates are likely to be constant across cross section units. Hence, we can avoid one of the problems of time series analysis - the relevant opportunity cost of money is not so easily measured. Second, cross sectionally, our money can be consistently measured, while time series analyses often suffer from the problem of the changes in the composition and definitions of an aggregate monetary measure. Moreover, one can suppose that the relative prices and productivities that determine the amount of substitution among various forms of "money" do not vary across regions at a point in time or vary in a way that is uncorrelated with the scale of operation. Third, we can quantify shifts of money demand function more directly than the time series approach. Time series approaches obviously miss the structural changes that occur at the end of sample periods simply because they lack the relevant information. Our empirical model in this paper shares the same spirit as Mulligan and Sala-i-Martin (1992), but our estimation strategy is now armed with an explicit model of individual behavior and its implications for the behavior of the monetary aggregates and aggregate income discussed in Fujiki and Mulligan

(1995). We find stable cross sectional money demand functions from the Japanese data. In particular, our best estimates of income elasticity of an M2-Cash counterpart are in the range 1.2-1.4. Third, we make some additional progress on some empirical questions which were left unanswered by Mulligan and Sala-i-Martin (1992). Those include regional differences in purchasing power, the separate effects of firms and households on the aggregate demand for money, a distinction between the effects of the supply of banking services and the effects of the demand for money, estimation of an interest rate elasticity from macro time series data constraining income elasticity at the value of our stable cross sectional income elasticity, and the assessment of financial sophistication from the time effect estimates on the cross sectional money demand function.

The organization of this paper is as follows. Section 2 explains our theoretical model and the reason why a cross sectional regression of money demand is useful to recover some of the parameters of our structural model. Section 3 discusses our data. Section 4 investigates the dispersions of variables used in this study. Section 5 reports our regression results. Section 6 discusses our procedure for recovering an interest rate elasticity and degrees of financial sophistication. Section 7 concludes by summarizing the results and by suggesting how knowledge of various structural parameters might be relevant for monetary policy.

2. The Production Model of Money Demand and Identification of Parameters from Aggregate Data

Here we begin with a parametric model for production by households and firms which is discussed in section 5 of Fujiki and Mulligan (1995). Useful money demand functions are derived for both types of agents. It is then shown how some of the structural parameters (ie, parameters of the production/utility functions) can be identified from aggregate data. A brief review of previous empirical studies of Japanese money demand and their problems complete this chapter.

2.A. A Parametric Model for Households and Firms

Suppose that an agent i produces his final output y_{it} at date t using a input $x_{1,it}$ as well as the quantity of transactions services T_{it} following the technology (all of the Greek parameters are positive constants): [1,2]

$$y_{it} = f(x_{1,it}, T_{it}, \lambda_f) = \left[(1-\lambda_f) x_{1,it}^{\frac{\gamma-\beta}{\gamma}} + \lambda_f \left(\frac{\gamma-\beta}{\gamma-1}\right) T_{it}^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-\beta}} \tag{1}$$

$$\lambda_f \in (0\,,\,1)\;,\quad \beta > 0\;,\quad \gamma \in (0\;,\;\min\,(1\;,\;\beta)\;)$$

$$T_{it} = \phi(m_{it}, x_{3,it}, A_{it}) = A_{it}\left[(1-\lambda_\phi) m_{it}^{(\psi_\phi-1)/\psi_\phi} + \lambda_\phi x_{3,it}^{(\psi_f-1)/\psi_f} \right]^{\psi_\phi/(\psi_\phi-1)} \tag{2}$$

where m_{it} denotes real money balances, $x_{3,it}$ denotes a input used in the production of transactions services. The production of transactions services is a CES function, with λ_ϕ and λ_f in the interval (0,1). Transactions services are not,

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[1]For $\gamma = 1$, log T replaces the power function of T. For $\gamma = \beta$, log replaces the power function whose argument is a term in small square brackets to the $\psi_f/(\psi_f-1)$ power. For ψ_ϕ or ($\gamma = \beta$) equal to 1, the corresponding CES aggregator is replaced by a Cobb-Douglas aggregator, with exponents λ_f, $(1-\lambda_f)$ or λ_ϕ, $(1-\lambda_\phi)$.

[2]It is straight forward to allow for more nonmonetary inputs without changing the implications that are derived below. For example, one could replace x_1 with a homogeneous function of several inputs. Instead of representing a single rental rate, q_1 is interpreted as a price index for the rental rates of the several inputs.

however, aggregated with x_1 in a homogeneous way. Notice that the exponent on the first term is $(\gamma-\beta)/\gamma$, whereas the exponent on the second term is $(\gamma-1)/\gamma$. We will show that scale elasticities will differ from one when these two exponents differ (ie, when $\beta \neq 1$).

Agent i's choices of money m_{it} and other inputs $x_{k,it}$ (k=1,2) for period t minimize the rental cost r_{it} of producing output y_{it}, where cost is

$$r_{it} = q_{1,t}x_{1,it} + R_t m_{it} + q_{3,t}x_{3,it} \tag{3}$$

where $q_{k,t}$ is date t rental rates of the k-th input and R_t is the nominal interest rate at date t. Money is "rented" at rental price equal to the nominal interest rate. This formulation can be justified on the grounds that there exists an alternative asset which pays interest (in units currency units) at rate R_t but does not enter in the production of transactions services.

The minimum cost achieved is a function of the production level y_{it} and the prices R_t and $q_t=(q_{1t}, q_{3t})$. This cost function, familiar from standard microeconomic theory (eg., Deaton and Muellbauer (1980)), will be denoted $\Omega(y_{it},R_t,q_t,A_{it},\lambda_f)$:

$$\Omega(y_{it},R_t,q_t,A_{it},\lambda_f) \equiv \min_{X_{it},m_{it}} [q_t' X_{it} + R_t m_{it}]$$
$$\text{s.t.} \quad (1) \text{ and } (2)$$

where $X_{it} = (x_{1,it}, x_{3,it})$ The cost minimizing choices of money and other inputs are functions of output y_{it}, the nominal interest rate R_t, the rental rates of the other inputs q_t, and the level of financial sophistication A_{it}. The Hicksian or derived demand for m_{it} is what we will call the **derived demand for money**:

$$m_{it} = L(y_{it},R_t,q_t,A_{it}) = \frac{\partial\Omega(y_{it},R_t,q_t,A_{it})}{\partial R_t} \tag{4}$$

The second equality follows from Shephard's Lemma. [3]

One question that we can ask of this derived demand function is "How does the demand for money change as the level of production, y, changes?" This is just what we call the **production elasticity of money demand:**

$$\beta_L = \frac{\partial L\ (y,R,q,A)}{\partial y}\ \frac{y}{m}$$

If we consider the special case of firms, where y_{it} is the sales of firm i at date t and $x_{1,it}$ is a input such as labor, then one might think of the coefficient from a regression of firms' log money balances on their log sales as an estimate of β_L. Such estimates of sales elasticities can be found in Meltzer's (1963) study of firms. [4]

In the case of households, y might correspond to "household production", which is observed neither at the micro or macro levels. To think about alternative scale variables, we define a **Marshallian money demand:**

$$m_{it} = M(r_{it},R_t,q_t,A_{it}) \equiv L\ [\Omega^{-1}(r_{it},R_t,q_t,A_{it}),R_t,q_t,A_{it}]$$

Maintaining the analogy with standard microeconomic theory, we compute the Marshallian money demand function in two steps. First, the cost function Ω is inverted in order to obtain an "indirect production function" y as a function of r, R, q, and A. Second, the indirect production function Ω^{-1} is substituted into the derived money demand function to obtain the Marshallian money demand M.

In some macroeconomic models, it is important to distinguish income elasticities

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[3]The first and second derivatives of the cost function with respect to (q,R) exist almost everywhere.

[4]Of course, simple regressions of log money on log sales yield consistent estimates of β_L only if R, q and A are uncorrelated with sales and if money demand is log linear.

from **consumption elasticities of money demand**. Section 4 of our theory paper will follow Lancaster (1966) and suppose that consumption expenditures can be modeled as inputs into a household production function. Thus, in order to think about the relationship between consumption expenditures and money holdings by households, we need to use our production model to think about the relationship between the derived demand for money and the derived demand for other inputs.

As the level of production increases we can, for given nominal interest rate R, rental rates q, and financial sophistication A, trace out the optimal demands in the (X,m) space - an **expansion path**. Now pick a particular input X_j and consider the projection of the expansion path into the (X_j,m) plane. When X_j is a normal good, the expansion path for X_j and m can be expressed as a function g_j:

$$m_{it} = g_j(X_{j,it},R_t,q_t,A_{it}) \equiv L(H_j^{-1}(X_{j,it},R_t,q_t,A_{it}),R_t,q_t,A_{it}) \tag{5}$$

where $H_j(y,R,q,A)$ is the derived demand for x_j and $H_j^{-1}(x_j,R,q,A)$ is inverse of the derived demand for x_j.

Define the **jth input elasticity of money demand** as the elasticity of this expansion path:

$$\beta_j \equiv \frac{\partial g_j(X_j,R,q,A)}{\partial X_j}\frac{X_j}{m} \qquad j = 1 \ , \ \ldots \ , \ k$$

Propositions 5-8 in Fujiki and Mulligan (1995) show how the various elasticities of an expansion path are related to the corresponding elasticities of the Marshallian and derived money demand functions.

The production function (1) and (2) in this example lead to a fairly simple characterization of the expansion path:

$$
\begin{aligned}
\log m_{it} &= \log g_1(x_{1,it}, R_t, q_t, A_{it}) \\
&= \beta \log x_{1,it} - \gamma \log R_t + \pi_\phi(\psi_\phi - \gamma)\log \frac{q_{3,t}}{R_t} + \\
&\gamma \log q_{1,t} - (1-\gamma)\log A_{it} + \varphi(\psi_\phi, \gamma, \beta, \lambda_f, \lambda_\phi)
\end{aligned} \tag{6}
$$

φ is an intercept term that is a function of the production parameters only. The projection of the expansion path into the (m, x_1) plane has a constant elasticity of β. Holding constant q_3/R, the elasticity with respect to the nominal interest rate is the constant $-\gamma$. [5]

Increases in the level of financial technology, A_{it}, decrease the demand for money when γ is less than one, but increase money demand for $\gamma > 1$. The effect of technology on the demand for money depends on the interest elasticity of money demand. To see this, notice that holding constant q_3/R, the price of transactions services is the ratio R/A. Transactions services are more costly when q_3 and R increase, but are less expensive when m and x_3 are more productive. $\gamma < 1$ means that there are few possibilities for substitution of T for x_1, so a change in R/A - say because of an increase in A - does little to the demand for T. The productivity effect of A therefore dictates that the demand for m and x_3 fall. For $\gamma > 1$, the substitution towards transactions services outweighs the productivity effect so the demands for m and x_3 increase.

x_1, and x_3 need not be the same good for all agents. For example households may use a consumption good and labor while firms use capital and labor. All agents must use money, however. If agents are using different inputs, then (6) should be modified to allow prices q_1 or q_3 to vary across agents.

Fujiki and Mulligan (1995) argues that an expansion path such as (6) is only

[5]The expansion path is not log-linear in q_3/R; the constant π_ϕ in equation (7) is derived from a log linear approximation to this term.

one way to characterize the demand for money. The derived demand for money and the Marshallian demand for money are alternative characterizations. Propositions 3 and 6 in Fujiki and Mulligan (1995) describe some conditions for which the production elasticity of money demand is close to the cost and input elasticities. In particular, when the production elasticities of demand for the other inputs are one (on average), these elasticities approach each other as money's share of cost approaches zero. For the purposes of aggregation, we assume that these three elasticities are in fact equal. [6] Since we can see from (6) that the 1st input elasticity of money demand is β, we can use β to approximate the cost and production elasticities. Fujiki and Mulligan's (1995) Proposition 7 and Slutsky's equation tell us that the interest elasticity of the three types of money demand functions are also equal as money's share of cost goes to zero, so we can derive log-linear approximations to all three money demand functions:

$$\log m_{it} = \log g_1(X_{1,it},R_t,q_{it},A_{it}) = \beta \log X_{1,it} - \gamma \log R_t +$$
$$\pi_\phi \, (\psi_\phi-\gamma) \log\frac{q_{3,it}}{R_t} + \gamma \log q_{1,it} - (1-\gamma) \log A_{it} + \varphi(\psi_\phi,\gamma,\beta,\lambda_f,\lambda_\phi) \tag{7}$$

$$\log m_{it} = \log L(y_{it},R_t,q_{it},A_t) \approx \beta \log y_{it} - \gamma \log R_t +$$

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[6]The rental cost of money does not appear to be a substantial fraction of GDP in Japan. The ratio of M1 to GDP is about 0.26 in 1992(Economic Statistics Annual 1993, The Bank of Japan). Even at a 10% interest rate, the rental cost of money is only 2.6% of GDP. This is an even a smaller percentage if one allows for the fact that the sum of sales of firms and incomes of households would add up to much more than GDP.

The other requirement of Propositions 3, 4, and 5 - that an average of the production elasticities of the nonmonetary inputs be one - also holds as an approximation for this problem. As α_m approaches zero (holding constant relative prices), so must α_3 (because transactions services are produced according to a homothetic production function). The x_1 and x_2 terms will dominate the production function, so they must be used in proportion to production y. Note that $\alpha_m \to 0$ as $y \to \infty$ $(y \to 0)$ for $\beta < 1$ $(\beta > 1)$.

$$\pi_{\phi}\ (\psi_{\phi}-\gamma)\ \log \frac{q_{3,it}}{R_t} + \gamma \log q_{1,it} - (1-\gamma) \log A_{it} + (\text{constant}) \tag{8}$$

$$\log m_{it} = \log M(r_{it},R_t,q_{it},A_t) \approx \beta \log r_{it} - \gamma \log R_t +$$
$$\pi_{\phi}\ (\psi_{\phi}-\gamma)\ \log \frac{q_{3,it}}{R_t} + (\gamma-\beta) \log q_{1,it} - (1-\gamma) \log A_{it} + (\text{constant}) \tag{9}$$

where rental rates of the inputs other than money have been subscripted by i to allow for different agents to use different inputs.

For those agents that are households, r is equal to income which will be denoted I. For firms, the level of production y can be interpreted as sales. It will be assumed that income, rental rates and technology are lognormally distributed across households and that sales, rental rates and technology are lognormally distributed across firms:

for households:

$$\log I_{it} \sim N\left(\mu_{i,t}(h)\ ,\ \sigma^2_{It}(h)\right)$$
$$\log q_{j,it} \sim N\left(\mu_{j,t}(h)\ ,\ \sigma^2_{jt}(h)\right) \qquad j = 1,3$$
$$\log A_{it} \sim N\left(\mu_{A,t}(h)\ ,\ \sigma^2_{At}(h)\right)$$

for firms:

$$\log y_{it} \sim N\left(\mu_{y,t}(f)\ ,\ \sigma^2_{yt}(f)\right)$$
$$\log q_{j,it} \sim N\left(\mu_{j,t}(f)\ ,\ \sigma^2_{jt}(f)\right) \qquad j = 1\ ,\ 3$$
$$\log A_{it} \sim N\left(\mu_{A,t}(f)\ ,\ \sigma^2_{At}(f)\right)$$

For the sake of generality we allow prices (except the nominal interest rate) to differ across agents. Depending on the application, one might set the variances to zero so that all households face one price and all firms face another or, in addition, set $\mu_{j,t}(f) = \mu_{j,t}(h)$ so that both firms and households face the same price.

2.B. Firm Aggregates and Household Aggregates

Here we consider aggregation of the derived money demand functions of firms and then the aggregation of the Marshallian demand functions of households. We consider the firm's derived demand function - as opposed to Marshallian demand or an expansion path - for two reasons. First, the derived demand (8) follows the empirical literature by relating money balances to sales of the firm. Second, we argue in subsection 2.C. that, because sales is the scale variable, firms' derived demand can be readily combined with households' Marshallian demands to arrive at a national money demand equation that resembles those found in the macro literature. The derived demand for households, on the other hand, is not as useful because household production is unobserved. Fortunately, the three types of money demand functions have some similarities; the similarities can be exploited to derive aggregate relationships that are functions of production parameters such as β and γ.

Let $N_t(f)$ and $N_t(h)$ denote the number of firms and households in the economy at date t, respectively. $y_t(f)$ and $m_t(f)$ are the average sales and real money balances of firms at date t (ie, the sum of sales and money balances divided by the number of firms). $I_t(h)$ and $m_t(h)$ are date t average household income and real money balances. Using some properties of the lognormal distribution, we arrive at two aggregate money demand functions: one for firms and one for households:

$$\log m_t(f) = \beta \log y_t(f) - \gamma \log R_t + \pi_\phi(\psi_\phi-\gamma) \log \frac{q_{3,t}(f)}{R_t} + \gamma \log q_{1,t}(f) -$$
$$(1-\gamma) \log A_t(f) + \frac{1}{2} \beta (\beta-1) \sigma^2_{yt}(f) + \frac{1}{2} \pi_\phi (\psi_\phi-\gamma) [\pi_\phi(\psi_\phi-\gamma) - 1] \sigma^2_{3t}(f) +$$
$$\frac{1}{2} (1-\gamma) (2-\gamma)\sigma^2_{At}(f) + \frac{1}{2} \gamma (\gamma-1) \sigma^2_{1t}(f) + (\text{covariances}) + (\text{constant})$$

$$\log m_t(h) = \beta \log I_t(h) - \gamma \log R_t + \pi_\phi(\psi_\phi-\gamma) \log \frac{q_{3,t}(h)}{R_t} + (\gamma-\beta) \log q_{1,t}(h) -$$
$$(1-\gamma) \log A_t(h) + \frac{1}{2} \beta (\beta-1) \sigma^2_{It}(h) + \frac{1}{2} \pi_\phi (\psi_\phi-\gamma) [\pi_\phi(\psi_\phi-\gamma) - 1] \sigma^2_{3t}(h) +$$
$$\frac{1}{2} (1-\gamma) (2-\gamma)\sigma^2_{At}(h) + \frac{1}{2} (\gamma-\beta) (\gamma-\beta-1) \sigma^2_{1t}(h) + (\text{covariances}) + (\text{constant})$$

For scale and price elasticities of one and no correlation among the scale and price variables, household and firm aggregate demand functions are identical to their micro counterparts (8) and (9). For scale elasticities different from one, the variance of sales and the variance of household income enter the aggregate equations. Variances and covariances of the price variables also enter the aggregate equations, but disappear if the prices are the same among firms and the same among households.

2.C. National Aggregates

For scale and price elasticities different from one, the definition of an "economic agent" is important. Section 2 began with households and firms as agents. Thus, in order to derive macro money demand functions in terms of money and income *per capita*, we need to keep track of the number of firms and households per capita. Define N_t to be the size of the population at date t. $\eta_t(f) \equiv N_t(f)/N_t$ and $\eta_t(h) \equiv N_t(h)/N_t$ denote the number of firms and households per capita. Let ν_t denote aggregate sales as a fraction of aggregate household income:

$$\nu_t \equiv \frac{N_t(f)}{N_t(h)} \frac{y_t(f)}{I_t(h)}$$

Using the aggregate firm money demands and the aggregate household money demands from the previous subsection - together with a loglinear approximation of $\log(m_t(f) + m_t(h))$ - we derive an expression (10) for real money balances per capita:

$$\begin{aligned}
\log\left(\frac{M_t}{P_t\ N_t}\right) &= \beta \log y_t(h) - \gamma \log R_t + \\
&\pi_\phi(\psi_\phi-\gamma)\left[\omega \log \frac{q_{3,t}(f)}{R_t} + (1-\omega) \log \frac{q_{3,t}(h)}{R_t}\right] + \\
&\omega\gamma \log q_{1,t}(f) + (1-\omega)(\gamma-\beta) \log q_{1,t}(h) - \\
&(1-\gamma)\left[\omega \log A_t(f) + (1-\omega) \log A_t(h)\right] + \\
&\omega \log \eta_t(f) + (1-\omega) \log \eta_t(h) + \beta\ \omega \left[\log \nu_t + \log \frac{\eta_t(h)}{\eta_t(f)}\right] + \\
&\frac{1}{2}\beta(\beta-1)[\omega\ \sigma^2_{yt}(f) + (1-\omega)\ \sigma^2_{It}(h)] + \text{(other covariances weighted by } \omega,\ 1-\omega) \qquad (10)
\end{aligned}$$

Beginning with the first four terms (the first line) of equation (10), we see that, like its micro counterparts, the per capita demand for money depends on average household income, the nominal interest rate and the ratio q_3/R with elasticities β, $-\gamma$ and $\pi_\phi(\psi_\phi-\gamma)$. When the average price q_3 is different for households and firms, however, the geometric mean of the two q_3/R ratios (one for firms, one for households) enters the aggregate equation. The weight ω, can be approximated by the share of the money stock held by firms (as opposed to households).[7] Terms reflecting averages of the price of x_1 and the level of financial technology enter the aggregate money demand equation separately for firms and households. Per capita money demand also depends on the number of firms and households per capita as well as the ratio of aggregate sales to household income (ν_t). These three terms, roughly speaking, represent the degree of vertical integration in the economy. The more stages involved in the production process, the greater the demand for money. This vertical integration result follows from the assumption that *a firm* and *a household* are the demanders of money. Economies of scale ($\beta < 1$) cannot be exploited by pooling money holdings across firms or across households while diseconomies of scale ($\beta > 1$) cannot be avoided by subdividing money holdings within the firm or within the household.

Finally, for given average sales and average income, the dispersion of income and sales across agents affects aggregate money demand to the extent there are economies (or diseconomies) of scale in the holding of money.

2.D. Identification of Parameters from Aggregate Data

The aggregate money demand equation (10) indicates that, with enough data, one could obtain consistent estimates of some of the structural parameters of the model such as β, γ, and perhaps ψ_ϕ. The scale elasticity is interesting for economic theory as various models of the demand for money differ on the presence and extent of scale economies. γ and ψ_ϕ reflect the own price elasticity of money demand and are therefore indicative of the welfare cost of inflation and relevant for computing the optimal monetary policy (see Lucas (1994) for a discussion and

[7] ω derives from an approximation to $\log(m_t(f) + m_t(h))$

for references). However, estimation of (10) requires that (i) one has a time series on the prices q_1 and q_3 and the level of financial sophistication *or* (ii) all cross-price elasticities are zero or (iii) the cross-prices and the level of financial technology are uncorrelated with household income and the nominal interest rate. Condition (iii) is certainly violated if we estimate equation (10) in levels. Financial technology has grown over time as has household income. Or, if one prefers to think of financial sophistication as endogenous, the rental rate of financial technology (which might be modeled as q_3 in our setup), such as the computer, has fallen over time. One solution to this problem might be to estimate (10) in differences. Perhaps high frequency movements in income are not associated with high frequency movements in financial technology. However, the same might not be true for short-term movements in the nominal interest rate. We can imagine that economy-wide stocks of financial technology (which we might model as the good x_3) are fixed in the short run. A rapid increase in the nominal interest rate will increase the demand for the technology which, because stocks are fixed, must result in an increase (but less than proportional) in the rental rate q_3. In other words, q_3 will be correlated with R at high frequencies. [8]

This has led some studies to use cross-sections of regional aggregates to identify the production parameter β.[9] The idea is that within Japan, all agents have fairly equal access to financial technology. Thus it is assumed that the exogenous level of financial technology A, the rental price of financial machines (q_3), and the nominal interest rate are all constant in a cross section of regions. γ and ψ_ϕ can then be estimated in levels using aggregate time series

[8]This problem may also occur with seasonal data because the stock of machines such as computers may not vary across seasons, but the demand for their services might.
[9]Mulligan and Sala i Martin (1992) is one example.

data by imposing that β correspond to its estimate from the cross sections. We expect consistent estimates as long as q_3 and A are uncorrelated with R in the time series. The basic specification of money demand function used in this paper is

$$\ln\left(\frac{\text{Money}}{\text{CPI}}\right)_{it} = b0\cdot(T) + b1\cdot\ln\left(\frac{\text{Income}}{\text{CPI}}\right)_{it} + b2\cdot Z_{it} + \varepsilon_{it}, \tag{11}$$

where T is a time effect, Z shows the vector of prefecture variables discussed later and b0, b1 and b2 are the vector of coefficients to be estimated and subscript i means prefecture and subscript t means time. Both money and income are normalized by the population.[10] Readers may complain that our cross sectional approach cannot recover interest rate elasticity, therefore it misses one of the most interesting structural parameters. However, under the assumptions listed above, we can recover the interest rate elasticity from macro data, after controlling for the value of income elasticity obtained from cross sectional data.

Before moving on the discussion of our prefecture data, we review former literature of empirical investigations of Japanese money demand, the problems inherent to these studies.

2.E. Literature Review

To our best knowledge, the study of Japanese money demand has always used time series data. Yoshida (1990) summarized the history of conventional studies of money demand, fitting the Error Correction Model to Japanese quarterly macro data. Yoshida and Rasche (1990) estimated a Vector Error Correction Model of Japanese

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[10]The timing of the usage of each variable in 1970 are as follows. We use income in 1970 fiscal year, March 1970 money data, CPI 1970 average, population of October 1 1970 and national deflator is mean of regional CPI in 1970.

M2+CD demand (with quarterly data). They find that the equilibrium real income elasticity of M2+CD was about 1.2 throughout the period 1956:1-1985:2. It is well known that the deregulation of Japanese money markets started in the middle of 1985, and they investigated whether the equilibrium income elasticities had changed after 1985 due to the deregulation of interest rate. They added a time dummy variable that took on the value of one after 1985:3 and took zero before 1985:3 to their Vector Error Correction Model, and found that the time dummy absorbed all of the effect of the deregulation of interest rate, and the rest of the parameters of money demand function unchanged from the parameters estimated from the data 1956:1-1985:2. Therefore they claimed that their equilibrium income elasticity was stable even after adding the observations from 1985:3 to 89:2. Rasche (1990) estimated a Vector Error Correction Model of Japanese M1 demand (with quarterly data). He advocated estimates of 1.0 for the long run income elasticity and -0.5 to -0.6 for the interest rate elasticity. McKenzie (1992) introduced the effect of foreign assets on the Japanese money demand function, by including the rates of return on foreign currency assets into the set of explanatory variables. He found that the relevant variables for money demand function were interest rate, a transaction variable, and a lagged value of money stock for the case of M1. For the case of M2, the rate of inflation was important in addition to the variables listed above.

Japanese conventional studies on money demand had the following drawbacks due to the fact that they used time series data. First, there is no agreement about the relevant interest rate. Second, due to the problem of the financial innovation, it is difficult to settle on a consistent definition of money over long periods of time. Third, the problem of the stability of money demand function has never been resolved.

For the sake of the demonstration of those problems, we display some regression estimates of the income elasticity of money demand. For this illustration we follow the tradition of using quarterly data on real M2+CD deflated by the GNP deflator, real GNP, the overnight call rate, and annual average of the interest rate of interest bearing bank debentures (maturity 5 years) to estimate a money demand function. The equation to be estimated is

$$\ln(\text{Real M2CD})_t = b0 + b1 \cdot \ln(\text{Real GNP})_t + b2 \cdot \ln(\text{Interest Rate})_t + \varepsilon_t, \qquad (12)$$

where M2CD is average of the amount of M2+CD within the quarter. The results of level estimation in table 1 suggest that the income elasticities are 1.2 to 1.5, and short term interest rate elasticities are something like -0.03 and long term interest rate elasticities are around -0.07. However, unusually low values of Durbin-Watson statistics suggest a missspecification of these regressions. For example, once first differenced data are used, we see dramatic changes: income elasticities fall to 1.0 (without constant term) or 0.6 (with constant term). On the other hand, the absolute value of interest rate elasticities increased to 2.2-2.3 (without constant term) and 1.8-1.1 (with constant term).

Table 1 about here

The conventional approach to the money demand function gives us unstable income elasticities of money demand, however we can estimate the long-run income elasticity of money demand by recovering the cointegrating vector of ln(Real M2CD) and real income. To this end, we first test the existence of the unit root for ln(real M2+CD) and ln(Real GNP). Using the sample period of 1967:2-1993:1, we find that ln(real M2+CD) and ln(Real GNP) have a unit root around linear time trend according to the augmented Dicky-Fullyer test.[11] Phillips-Ouliaris test for

[11]We put six lags of differenced term to conduct ADF test. ADF test statistics are -3.01 for ln(real GNP) and -3.24 for ln(Real M2+CD). The critical value to reject

cointegration between ln(real M2+CD) and ln(Real GNP) suggests the existence of cointegration between those two variables.[12] Using various cointegration regression technique such as Fully Modified estimation of Phillps-Hansen and Canonical Cointegration Regression, we estimate the long-run income elasticity of money demand to be 1.5-1.6.[13] It will be quite interesting to compare those results to our cross sectional income elasticity.

3. Data

We have compiled four series of estimates of prefecture money stock for 46 prefecture and three series of scale variables to estimate a money demand function from cross-sectional data.[14] This section reviews the definition of Japanese money supply statistics, our measure of prefecture money aggregates, scale variables, and various conditioning variables used in the later analysis.

3.A. Japanese money supply statistics

3.A.I. Aggregate Monetary Measure

For Japan, three measures of money supply are common; M1, M2+CD, and M3+CD. Table 2 shows the summary of Japanese monetary aggregates as of March 31 1990. Compared with M2+CD, which is Japanese standard monetary measure, M1 accounts for 25 percent of M2+CD, and M3+CD is about 1.6 times M2+CD. In order to understand our

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the null hypothesis of the existence of the unit root at 5% level is -3.46. All computations are done by COINT2.0 for GAUSS.

[12]The test statistics is -4.051, and the critical value at 5% significance level is -3.915. Computation is done by COINT2.0 for GAUSS.

[13]The value of cointegrating vector between ln(Real M2+CD) and ln(Real GNP) were 1.484 (t-value 114.8) for OLS, 1.568 (t-value 40.6) for the Fully Modified estimation method, and 1.535 (t-value 42.8) for Canonical Cointegration Regression. All estimations are done by the statistical package COINT 2.0 for GAUSS.

[14]We excluded Okinawa prefecture.

method of computing cross sectional counterparts of aggregate monetary measure from prefecture deposit survey, one must understand the coverage of the financial institutions and deposits in the aggregate monetary statistics.

Table 2 about here

3.A.II. Financial Institutions[15]

The coverage of financial institutions used to compile M1 and M2+CD are "all banks", the community (shinkin) banks, the Norinchykin bank, and the Shokochukin bank. M3+CD covers post offices and agricultural and fishery cooperatives, the credit cooperatives, the labor credit associations. Table 3 shows the summary of the distribution of deposits among financial institutions. About fifty percent of deposits exist in "all banks". The community banks, the post office, and the agricultural cooperative associations account for the most of the rest of deposits. Therefore we shall discuss the nature of these major financial institutions. First, "all banks" are classified as the commercial banks, the long term credit banks, the trust banks and the specialized foreign exchange banks. Among them, the commercial banks (the city banks, the regional banks, and the foreign banks resident in Japan), which focus on short term lending and the acceptance of short term deposits, are the most important financial institutions that accept deposits. The city banks have the network of their branches throughout large Japanese cities, and their important customers are large scale companies. The regional banks are the miniatures of the city banks whose major activities are limited within the prefecture where their headquarters are located, and their important customers are

[15]See the details on Japanese financial institutions and government regulations on banking industry for Federation of Bankers Associations of Japan (1994) or Suzuki (1991).

the medium sized businesses in each prefecture.[16] Second, the community banks engage in the same activities as ordinary commercial banks do, apart from the fact that the community banks are operated by the membership system and their branches are restricted to a local area. Third, the Japanese post office has been allowed to accept deposits since 1875, and this has been one of the important sources of Treasury Investments and Loans. Originally post office deposits are the means of absorbing small lot individual deposits in the rural area. Therefore the amount of the deposit per individual has an upper limit, while there are favorable treatments of the taxation on the interest rate earnings from deposits in the post office. About 80 % of deposits in the post office are fixed-amount postal savings as of March 31, 1990. Fixed-amount postal savings may be withdrawn without prior notice at any time six months after the date of making deposits, and its interest rate is fixed. Hence, the interest paid for fixed-amount deposits sometimes dominates the short term deposit rate offered by the commercial banks. Finally, the agricultural and fishery cooperative associations can accept saving deposits and installment deposits from the member farm and fishery households, and can provide the loan of funds necessary to finance the investment for the agricultural business. The agricultural cooperative associations exist every village, town and city throughout Japan. There are prefecture unions of agricultural cooperative associations, called the Shinnoren, in every prefecture. The deposits absorbed in the local agricultural cooperatives are concentrated to the Shinnoren. The Shinnoren send their excess

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[16]The regional banks in this article include the Sogo banks, which changed into regional banks in 1989. "All banks" includes financial institutions which specialize in lending long term funds, such as the long-term banks and the trust banks, and the specialized foreign exchange banks (The Bank of Tokyo), which specialized in the finance related to foreign trade. Those institutions have less domestic branches than other commercial banks and are allowed to issue bonds. Hence the deposits in those institutions are relatively small.

deposits to their national union, the Norinchykin bank.

Table 3 about here

3.A.III. Deposits Included in the Aggregate Monetary Measure

The coverage of the types of the deposits in the aggregate statistics are as follows; M1 is the sum of cash currency in circulation and total demand deposits, net of the deposits held by the financial institutions. M2+CD adds saving deposits and Certificates of Deposit to M1. M3+CD adds trust accounts to M2+CD. Table 4 shows the weights of deposits in "all banks". We can divide deposits into demand deposits versus saving deposits. Among them, current deposits, ordinary deposits and time deposits are the most important. First, current deposits are deposits that the depositor may demand as freely as his needs as require. Corporations use this account for the sake of settlement, and usually they make a current account transaction contract which let checks, promissory notes, or bills of exchanges be payable at the banks. Current deposits have not paid interest since 1944. Second, ordinary deposits are mostly held by the individuals and corporations with temporary excess funds, an interest rate which has been regulated by the monetary authority throughout the sample periods discussed in this paper, and not allowing depositors to write checks, and require the presentation of passbook and registered seals. Due to financial innovations, ordinary deposits offer various services: withdrawals from ATM machines, automatic payment services such as the transfer of funds, pension dividend payments, public utility charges, taxes, insurance premiums and installment credit payments. Since 1972, the automatic lending provision that uses the time deposit as an collateral are available. The automatic transfer service between ordinary deposit and time deposit became available since 1983.[17]

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[17]*Notice deposits* are the deposits that must be left in the account for seven days

Third, the banks offer time deposits. The interest rate for time deposits has been regulated, however, there are large lot time deposits, which are allowed to pay unregulated interest rate since 1985. As of 1990 March 31, 61% of time deposits have unregulated interest rates. The minimum amount of large lot deposit required to enjoy an unregulated interest rate has decreased steadily.[18] The financial institutions that are authorized to accept deposits are allowed to issue CDs since 1979. The interest rate for CDs are not regulated, and CDs may be sold to the third parties. Corporations, public sector cooperatives and local government purchase CDs to invest their large lot money. As of March 31 1990, "all banks" have issued 199,208 million yen of CDs outstanding[19].

Table 4 about here

3.B. Prefecture Money Aggregates[20]

We compute four types of prefecture money stocks from deposit survey data. We do our best to make the data from the deposit survey comparable to money supply statistics. This subsection discusses the prefecture deposit survey, and our

after placement, but may be withdrawn with two days' notice at any time thereafter. Companies use this type of deposit for the sake of investing temporary surplus of funds. Interest rates are 0.25 percent higher than those of ordinary deposits. *Deposit for tax payments* accepts the funds to pay taxes with the interest rate 0.75 percent higher than those of ordinary deposit without taxation. Withdraws are allowed only for the timing of tax payment. *Special deposit* are miscellaneous deposits for such purposes as repositories for temporary funds in transit or held in custody.

[18]*Installment savings* are a type of savings instrument for individuals, which is similar to the installment time deposits used for the particular targets such as education, housing, and travel. These are usually provided by the local financial institutions. *Other deposits* includes non-resident yen deposit (20,297 million yen as of March 31 1990) and foreign currency deposits (352,847 million yen as of March 31 1990).

[19]*Economic Statistics Annual 1990,* p.188.

[20]Data source: Bank of Japan, *Prefecture Economic Statistics*, 1956-1992. Note that the location of branches of each financial institutions determined the prefecture the deposit belonged to.

measure of MF1, MF2, MF3 and MFP in turn.

3.B.I. Prefecture Deposit Statistics

Prefecture deposit statistics are available from 1955 to 1990 (surveyed at the end of March). We have prefecture breakdown of the deposit in "all banks", the community banks, shokochukin banks, labor credit associations, agriculture and forestry cooperatives and the post office. These statistics include deposits held by individuals, corporations, local governments and public enterprises, while they do not include deposits from nonresident and foreign currency deposits. Since these statistics are based on a different survey from the money supply statistics, we do our best to make the deposit data comparable with current Japanese money supply statistics. First, our measure includes deposits held by the financial institutions, while money supply statistics exclude them[21]. But the breakdown of deposits held by financial institutions by prefecture are available for "all banks" only. Hence, we eliminate the deposit held by the financial institutions for "all banks" only, but we believe that this should be good enough adjustment, since most of the deposit held by the financial institutions would exist in "all banks".[22] Second, the prefecture breakdown of CDs outstanding does not exist. But as can be

[21]Financial institution in this statistics means a institution that accepts deposits and lends it to someone else. Hence, it does not include money brokers in the call markets, and security firms and so forth.

[22]Note that two plausible reasons why some financial institutions need to have deposits in the other financial institution would be as follows; (1) small community banks want to buy large lot saving deposit at the city bank to utilize their excess funds, (2) small community banks which operates different regions within the same prefecture and do not have the transaction with Bank of Japan may use the account in the regional banks which had the network of branch throughout the prefecture for the sake of cleaning up the debt and liability among them. The amount of deposit made by the financial institutions in shinkin banks are at most 3% of their total deposit, and the amount of total deposit in the Shokochukin Bank is negligible compare to the other institutions.

seen in table 2, the percentage of CD in M2+CD was about 3% in 1990, and we decided to neglect it. Third, we have no way to recover the regional distribution of cash. Finally, prefecture breakdowns of demand deposit and savings deposit are possible only for "all banks". Due to these limitations of the data discussed above, we will define our prefecture monetary aggregates as follows.

MF1

MF1 is our counter part of M1 minus cash. Due to the limited of the availability of the prefecture breakdown of demand deposit versus savings deposit, MF1 is defined as the demand deposit held by the individuals and cooperates in "all banks". This series is available from 1960 to 1990. Note that due to the changes of some banks that are not included in "all banks" into "all banks" or mergers, MF1 has discontinuities in 1968, 1976, 1983, 1984 and 1989.

MF2

MF2 is our counterpart of M2 minus cash. The definition of MF2 is the sum of the deposit in "all banks", community banks and Shokochukin Bank. We do not include the data for the Norinchykin bank, but almost all of their deposits come from the agricultural cooperatives, which is not included in the financial institutions covered by M2+CD. Therefore the addition of norinchykin banks would be a double count of same deposits. MF2 consists of both demand deposit and savings deposit. This series is available between 1955 and 1990 and is consistently measured throughout sample period.

MF3

MF3 is our counterpart of M3 minus cash.[23] MF3 covers the deposits in the post office, credit cooperatives, labor credit association, agricultural cooperatives and the fishery cooperatives in addition to the financial institutions covered by the MF2. We include deposits in the local agricultural and fishery cooperatives but ignore the prefecture union of these institutions (Shinnoren), since a fairly large part of the deposits in the Shinnoren are deposits made by the local agricultural and fishery cooperative associations. These series are available between 1955 and 1990. These statistics are consistently measured throughout sample periods. Table 5 shows the breakdown of our MF1, MF2 and MF3 as of March 31, 1990. We find the same patterns of the distribution of deposits among financial institutions which we have observed in table 2. Table 6 summarizes the correspondence of the coverage of financial institutions between Money supply statistics and our prefecture monetary measure.

Tables 5 and 6 about here

3.B.II. Personal Deposit Data

The data for the individual deposits are available from *The Prefecture Economic Statistics*. These data are surveyed at the end of March since 1980. We compute the prefecture money stock between 1980-1990. Since some part of the data are based on the estimates from the annual reports of the financial institutions, only annual data is available. These statistics allow us to deal with the differences in the cash management of the individuals and the cooperatives plus the local governments. In particular, the individuals and the small business may not make deposits across prefecture borders apart from the metropolitan areas of Tokyo and Osaka, and hence these statistics help us to interpret of the income elasticity

[23]M3 includes trust accounts, while MF3 does not.

of deposit demand.

Major drawbacks of the personal deposit data are as follows. First, they do not show the decomposition of the demand and savings deposits. Second, they include the deposits of small businesses for the sake of business operation as long as the deposit is done in the name of individual. Third, the definition of individual deposits seems to be somewhat different among the financial institutions. Fourth, deposits are classified the place where the branch exists, but credit cooperatives and the community banks are classified by the prefecture where their headquarters exist. We have two more remarks. First, apart form the credit cooperatives, these statistics do not include "deposits without name". Second, post office deposit do not include deposits which related to former Japanese colonial regions.

MFP

We defined our MFP as the sum of deposits made by the individuals in "all banks", community banks, post offices, agricultural cooperatives, fishery cooperatives, credit cooperatives, and labor credit associations[24]. As can be seen in table 7, while "all banks" explain about 40 % of individual deposits, substantial proportion of deposits are seen in the post office and agriculture and forestry.

Table 7 about here

3.C. Scale variables

3.C.I. Prefecture Income Statistics

The research institute of economy in the Economic Planning Agency of Japan

[24]We do not include the data for the Shinnoren and Shingyoren (they are prefecture federation of agricultural cooperatives and fishery cooperatives), but almost all of their deposits come from the agricultural or fishery cooperatives.

publishes the prefecture accounts, which are the prefecture version of the GNP statistics. The department of statistics in each prefecture estimates the prefecture accounts following the guidelines of the Economic Planning Agency of Japan for every fiscal year (from April to March of the following year) while the differences in the estimation method in each prefecture make the sum of the items over the prefecture accounts statistics slightly different from their counterparts in the GNP statistics. These data date back to 1955, but the method of compiling them changed several times. Currently, we have three series of data consistently estimated for the fiscal year periods 1975-90, 1970-79, 1955-71. We try to use the latest estimates: 1955-71 estimates for 1955-69, 1970-79 series for 1970-1974, and all of the 1975-1990 series. We utilize three scale variables; prefecture income, employee income and consumption.

3.C.II. Prefecture Income

Prefecture income is the prefecture counterpart of GNP. Because our measure of money includes deposits held by corporations, we prefer a measure of income that includes the activity of corporations. To this end, we use prefecture income.

3.C.III. Consumption

Consumption per capita is taken from the final expenditure of households in the prefecture income statistics. Due to limitations of the data set in the old days, the data before 1962 are not used. 1963-65 were annual estimates, not the fiscal year estimates as the other income statistics.

3.C.VI. Employee Income

Employee income data are available from the prefecture accounts statistics. A substantial part of this income measure is explained by the wages and the social security benefits incurred by the employer.

3.D. Conditioning Variables

We conduct the analysis of money demand functions with cross sectional data. In the case of cross sectional regressions, there may be some important control variables which are not relevant for aggregate time series data. Our theoretical model in Fujiki and Mulligan (1995) suggests that we need to control the level of technology for each prefecture in order to estimate money demand function cross sectionally. To this end, we introduce three conditioning variables following Mulligan and Sala-i-Martin (1992): population density, the percentage of net prefecture product explained by the primary industry, and prefecture fixed effect.[25] Even after controlling for these variables, the error them of money demand function might be correlated with the level of income. Hence, we prepared the ratio of job offers to applicants for the instrumental of real income. We will discuss such variables in turn.

3.D.I. Population Density (PD)

To take differences in the industry structures among regions into account, we use is population density. We will call this variable PD hereafter. This data uses the population of each prefecture as of the beginning of October of each year.

3.D.II. The Share of Primary Industry to Prefecture Net Product (SPI)

[25]Mulligan and Sala-i-Martin (1992) discussed the reason why those conditioning variables are relevant for our money demand function.

The other variable to trace the differences in the financial technology between rural area and urban areas is the percentage of the net prefecture product explained by the primary industry (Agriculture, Forestry and Fisheries) from the prefecture accounts statistics. We will call this variable SPI hereafter. There are some missing data points, which we replace with plausible numbers: data for Tochigi prefecture in 1955 is missing and we set it at the level of 1956 data, data for Osaka prefecture between 1955-57 is missing, and we set them at 2%, which is the level of 1958 data.

3.D.III. Prefecture Fixed Effect

Mulligan and Sala-i-Martin (1992) argued that if the financial sophistication, the structure of banking industries and the differences in the levels of prices in regions are fairly persistent, prefecture fixed effects should adequately proxy for them. In the case of Japan, since the structure of banking industry has been fairly stabilized due to the regulation of the allocation of branches by the Ministry of Finance, the introduction of prefecture fixed effect might make sense.

3.D.IV. Ratio of Job Offers to Applicants

Japanese public employment security office publishes the data for the number of job applicants and the number of job offers in the office. The bid and offer of the job made for the public employment office are valid for two consecutive months. We use the ratio of these two variables in some of our analysis.

3.E. Deflators

Regional Consumer Price Difference Index

We have the regional consumer price difference index (1960-90, calendar year average) and the regional retail price difference index (1955-59, calendar year), which measure the cross prefecture differences in the level of retail prices in the capital cities of each prefecture at one point in time. Using a time series of the CPI index of Tokyo (1934-1936 average base, calendar year), we construct the deflator for each prefecture in every year. Note that the relative CPI index among prefectures compare the levels of prices in the capital city of each prefecture, so, it cannot be the perfect measure of the differences in the level of prices. Discussions on the relationship between regional consumer price and income appear in the following section.

4. Dispersions of Variables

This section discusses the dispersions of variables used in the later analysis. The dispersion of variable x is defined as the standard deviation of log(x).

4.A. Prefecture Deposits

Mulligan and Sala-i-Martin (1992) showed that their U.S. state money aggregates had large variations, that states were not miniature replicas of the U.S. We can demonstrate here that our Japanese prefecture money aggregates have quite similar dispersions as their U.S. counterparts.

Figure 1 shows the cross prefecture standard deviation of log per capita MF1, MF2, MF3 and MFP deflated by our prefecture CPI. The dispersions of MF2, MF3 follow the same trend. The dispersions in time series aggregate counterpart are 0.676 for m1 deflated by cpi, 0.800 for m2 deflated by cpi. Why do MF1, MF2, MF3 and MFP have so different dispersions, and why are MF1 dispersions higher than MF2 dispersions? This is because our broader monetary measure includes more personal and local area deposits. Namely, MF1 essentially measures the deposits in the urban area whose major parts are corporate deposits, while MF2 adds a large amount of time deposits held by the individuals, and MF3 includes the post office deposits, which by itself explains about a third of individual deposits. Surprisingly, compared with figures 3 and 4 of Mulligan and Sala-i-Martin (1992), those two measures of dispersion show quite similar patterns to those of the U.S. counterparts, while the level of the dispersions are higher in the U.S. MFP shows stable and smaller dispersions than those of other monetary measures.

Figure 1 about here

4.B. Scale Variables

Figure 2 shows the cross sectional dispersion of our scale variables per capita deflated by regional CPI. As we expected, consumption is the most smooth variable among cross sectional units, and all of the income measures show the same trends; decline before 1975 and increased in the 1980s. Given the process of the shifting of the industry structure from agriculture to the services, it is quite natural that employee income shows the largest dispersion. We observed the convergence of three scale variables until the end of the high growth periods around 1975.

Figure 2 about here

4.C. Velocity

As can be seen in Figure 3, the standard deviation of the log velocity (defined by the ratio of prefecture income to our monetary measure) shows similar trends as dispersions of real money per capita. It works between 0.2 and 0.35 for the case of MF2 and MF3. MFP shows the smallest variation, and MF1 shows the largest fluctuation. Dispersions in time series aggregates are 0.097 for M1 velocity, 0.184 for M2 velocity. Hence we conclude that our prefecture velocity has pretty large dispersions compared with our time series counterparts.

Figure 3 about here

5. Regression Results

In this section, we will present our analysis of cross sectional money demand. First, we shall focus on the estimates using MF2 and the prefecture income. We will discuss the results of univariate regressions, regressions with conditioning variables, and instrumental variable methods. The effect of the choice of scale variables will follow. Second, given the basic results obtained from the analysis using MF2 and prefecture income, we will show the results using different measures of money, MF1, MF3 and MFP. For those three measures, selective interesting results will be reported.

5.A. Results of regressions of MF2 on Prefecture Income

5.A.I. Univariate Regressions

We begin with cross sectional estimates of the elasticity of money demand to prefecture income without adding any other conditioning variables. The solid line in Figure 4 shows the estimated income elasticities in each fiscal year using ln(Prefecture MF2 per capita/Prefecture CPI) for the dependent variable and ln(Prefecture Income per capita/Prefecture CPI) for the independent variable. As can be seen in table 8, all estimates are statistically significantly different from zero, and we find that the income elasticities are well above one and moving around 1.9 to 2.6. When we pool whole sample data and add time effects, the constrained income elasticity is 2.15 (s.e.=0.032), and we cannot reject the null hypothesis of a temporally constant income elasticity. Compared with the results of

Mulligan and Sala-i-Martin (1992), (See p.322, figure 9), these estimates of income elasticities from Japanese data are higher than those of the U.S. counterparts.

Figure 4 and table 8 about here

5.A.II. Adding Population Density

Four dashed lines in figure 4 report the estimated income elasticities holding polynomials of ln(PD) constant. Figure 4 shows that the introduction of ln(PD) reduces the level of income elasticities of money demand after 1974 compared to the case without ln(PD). The estimated coefficients of the polynominals of ln(PD) are not significantly different from zero for the case of including ln(PD) alone and ln(PD) and $\ln(PD)^2$. However the inclusion of $\ln(PD)^3$ and $\ln(PD)^4$ yields the coefficients on the polynominals of ln(PD) statistically significant. The relationship between real MF2 per capita and the polynomials of ln(PD) are nonlinear. Table 9 summarizes the long run pooling regressions holding time effect, income and the polynominals of ln(PD). We cannot reject the null of a constant income elasticity throughout the sample periods compare to the cross sectional regression. We might guess that the income elasticity of money demand is about 1.9-2.0 holding ln(PD) constant.

Table 9 about here

5.A.III. Adding the Share of Primary Industry to Prefecture Net Product

We add the share of primary industry to prefecture net product (SPI hereafter) to the explanatory variables. Figure 5 shows the cross sectional income elasticity holding SPI and polynomials of ln(PD). The solid line in figure 5 reports the income elasticities conditioned on prefecture income and SPI. The coefficients on SPI were negative except for the sample periods of 1970-72, and income elasticities conditioned on SPI take generally smaller values than those of univariate regressions, apart from 1970-72 periods (For these three years SPI are not significantly different from zero). Observe that compared to the results reported in figure 4, the use of SPI and polynominals of ln(PD) together as the conditioning variables generally make the income elasticities smaller than those of holding the polynominals of ln(PD) only, except for the periods of the early 1970s. However, note that the addition SPI for the regressions holding ln(PD), $\ln(PD)^2$, $\ln(PD)^3$ and $\ln(PD)^4$ yields the income elasticity of money demand not significantly different from zero after 1974. Hence, ignoring the results obtained from the sample period 1970-72, and the results after 1974 for the regressions holding SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$ and $\ln(PD)^4$, we see that our income elasticities swings around 0.8-2.0. To construct a plausible range of our income elasticities, we conduct long run pooling regressions. The results of long run pooling regressions using the entire sample holding SPI, polynomials of ln(PD) and time effect constant are summarized in Table 10. All of the pooling regressions are justified in a sense that we cannot reject the null of constancy of cross sectional income elasticity over time as can be seen in F-values in table 10. We conclude that our income elasticities are something like 1.2-1.4 judging from the results reported in table 10. Surprisingly, our findings are consistent with the time series vector error correction model by Yoshida and Rasche (1990), which found a stable income elasticity 1.2 which is significantly larger than 1 from 1956-1985 quarterly data.

Figure 5 and table 10 about here

In addition to the F-test for the long run pooling regressions, we report two additional pieces of evidence in order to validate the stability of our cross sectional income elasticity over time. First, following Yoshida and Rasche (1990), we introduced the time dummy that takes the value one after 1985 and zero before

1985 for the regressions presented in Table 10. We test if this time dummies can capture the effect of the deregulation of interest rate after 1985. None of the regressions reported in Table 10 give us the results that the time dummy is statistically significantly different from zero, namely, we did not find the evidence for the upward shift of all of the time dummies after 1985. This is the opposite to the result reported in Yoshida and Rasche (1990). Second, some readers may wonder whether our error terms in the regressions are serially correlated. We therefore conduct an additional analysis of a model

$$\ln\left(\frac{\text{Money}}{\text{CPI}}\right)_{it} = b0\cdot(T) + b1\cdot\ln\left(\frac{\text{Income}}{\text{CPI}}\right)_{it} + b2\cdot Z_{it} + \varepsilon_{it}, \quad \varepsilon_{it} = \rho\varepsilon_{i,t-1} + u_t \tag{13}$$

where Z is SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$. Since the GLS estimation of parameters require differencing, the set of time dummies cannot be estimated directly. Hence we regressed each variables on the time effect and used standard statistical package to estimate equation (13). The results of estimation suggests the estimates of ρ is 0.02 and b1 is 1.19 (s.e.=0.019). Compare to the OLS result of b1=1.22 holding the same conditioning variables constant, the modification of error term changes our results based on OLS only a little bit.[26]

5.A.IV. Cross-Prefecture Deviations from Purchasing Power Parity

The original specification in Mulligan and Sala-i-Martin (1992) was,

$$\ln(\text{Money})_{it} = b0\cdot(T) + b1\cdot\ln(\text{Income})_{it} + b2\cdot Z_{it} + \varepsilon_{it}, \tag{14}$$

Their specification added one more assumption that the level of price in each region is the same, or at least orthogonal to the level of income to equation (11). This assumption is unnecessary for our analysis since we can use a regional

[26]We estimate this model by the PANEL procedure in LIMDEP 6.0.

consumer price index. According to our computation, the correlation of log of CPI and log of real prefecture income by the cross sectional estimates is 0.06-0.14, which are statistically different from zero (except for the outliers of 0.03 in 1958 which is not significantly different from zero). Mulligan and Sala-i-Martin (1992) showed that if the partial correlation of real income and price was s, then the coefficient of income without taking into account of the differences in the regional price level, $\hat{\beta}$, and the true income elasticity, β, would be related as

$$\hat{\beta} = \beta + \frac{(1-\beta)s}{1+s}. \tag{15}$$

We know that the bias due to the failure to adjust for differences in the level of regional prices must be relatively small since s/(1+s) is at most 0.1. Nonetheless, we have made some progress on one of the open questions in Mulligan and Sala-i-Martin (1992). To see this in detail, Figure 6 plots the results of estimation with and without regional cpi.

Figure 6 about here

According to our computations, the average ratio of the cross sectional income elasticity estimated using nominal data to that estimated with real data is 0.963 for the case of univariate regression, 1.042 for the case of holding ln(PD), $(\ln(PD))^2$, $(\ln(PD))^3$, and $(\ln(PD))^4$ constant, and 1.189 for the case of holding SPI, ln(PD), $\ln(PD)^2$, $(\ln(PD))^3$, and $(\ln(PD))^4$ constant. Namely, the bias due to the omission of cpi for the case of univariate regression is only about 5.7%. As we increase our conditioning variables, the bias increases and is in the opposite direction to the case of univariate regression. Note that as long as we use aggregate time series deflator, for the case of univariate regression, the aggregate deflator will be absorbed by the constant term. Therefore our results are valid for all other kind of aggregate time series deflators.

We admit, however, that neither the GNP deflator nor the prefecture CPI is entirely successful at capturing regional differences in purchasing power. The prefecture CPI is intended to measure purchasing power in the capital city. The degree to which the capital city is typical of the rest of the prefecture varies across prefectures and probably relates to the importance of agriculture in the prefecture. Therefore, regional differences in purchasing power are a reason why one should include a variable like the prefecture's share of primary industry in an empirical money demand equation and why one might expect it to take on a negative sign as it has in all of our empirical work. Note that the usage of any aggregate time series deflators would mean just subtracting a constant term in the case of cross sectional regression, hence the parameters estimated by using the national deflators are the same as obtained from the regressions using the nominal data.

5.A.V. Choice of Scale Variables

There has been some debate in the literature about the choice of scale variable in a money demand equation. For two reasons, we are skeptical that this debate will be resolved empirically with aggregate time series data or with regional data such as ours. First, our theoretical analysis (Fujiki and Mulligan, 1995) has shown that one might expect income, consumption, and other scale elasticities to be equal regardless of the particular motive for holding money. Second, we believe that the empirically relevant difference between various scale variables is the degree of measurement error. Income and consumption, while they can be defined very precisely, are rarely measured precisely. Nor is there any reason to expect that measurement error is equally serious for the two variables. But if the two variables are measured with different degrees of error, then one may appear to improve the fit of a money demand equation merely because it is measured with less error.

Because some readers may not share our reservations, we estimate our money demand functions with a variety of scale variables. The general conclusion is that without conditioning variables, consumption elasticities are larger than that of prefecture income, and employee income elasticities are lower than prefecture income elasticities. Addition of the polynominals of ln(PD) makes the consumption elasticities close to prefecture income elasticity.

Consumption

We use consumption per capita taken from the final expenditure of household in the prefecture income statistics. Due to some limitations of the data set in the old days, the data before 1962 are not used. 1963-65 are calendar year estimates, as opposed to the fiscal year estimates of income.

Figure 7 compares the results of scale variable elasticities estimated from univariate regressions. Table 11 reports that the consumption elasticities at five year intervals. We find that consumption elasticities are larger than the prefecture income elasticities for the case of the univariate regression. Figure 8 compares the scale variable elasticities obtained from the results of the regressions holding $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant. Consumption elasticities are close to the prefecture income elasticity, particularly after 1972 (See table 12 for the estimates of scale elasticities every five year). Finally, figure 9 compares the scale variable elasticities obtained from the results of the regressions holding SPI, $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant. Consumption elasticities are again close to prefecture income elasticities apart from the 1980s, however, the standard errors of the estimated parameters of consumption are large after 1973, and the consumption elasticities obtained from this specification are not reliable (See table 13 for the size of standard error of the estimated consumption elasticities).

Figures 7-9 and tables 11-13 about here

Employee Income

Employee income, whose major components are wages and social security payments incurred by the employer, is used as the third scale variable. This scale variable excludes self-employment income. As can be seen figure 6, cross sectional employee income elasticities estimated from univariate regressions are remarkably stable around 1.4-1.6. This could reflect the fact that rural areas used to have smaller employee income per capita, since the rural areas have more agricultural population than the urban area. If the overestimation of income elasticity obtained from the univariate regression for MF2 were the result of over-representing the deposits of urban areas, employee income dampens this bias, since employee income per capita could over emphasizing the income of richer regions. The employee income elasticities obtained from the regressions conditioned with the polynomials of ln(PD), which are plotted in Figure 7, are again stable, however, the magnitude of elasticities seems to decreased after the 1970s, and typically took the value about 0.8-0.9. Note that table 12 shows the standard error of the employee income elasticities after 1970 typically took the value around 0.3-0.4, so that we are not sure about the shift of the mean of employee income elasticities. Figure 8 plots the employee income elasticities conditioned on the polynomials of ln(PD) and SPI. They become negative 1972-1989, and are not significantly different from zero for the most of our sample periods (1965-90).

5.B. The Demand for Money vs. the Supply of Banking

The goal of this paper has been to use cross-prefecture data to estimate certain structural parameters, by which we mean parameters of utility or production functions of agents in the economy. The first step in doing so is to aggregate the demand functions of the agents to arrive at a relationship between the aggregate quantity of money in the economy, aggregate income earned by residents of the economy, and other aggregate variables. However, we have attempted to estimate this aggregate relationship using deposits at banks in the prefecture - which need not be identical to money held by residents of the prefecture. Denoting money held by prefecture i residents at date t as $\ln(\text{Money})^*_{it}$ and the percentage difference between money held by residents of the prefecture and money deposited in banks of the prefecture as η_{it}, we have an obvious relationship between the variable required by the theory and the measure of money that is available to us:

$$\ln(\text{Money})_{it} = \ln(\text{Money})^*_{it} + \eta_{it} \tag{16}$$

Of course, our estimates of the income elasticity are still consistent if η_{it} is uncorrelated with prefecture income. However, there are reasons to believe that η_{it} is positively correlated with prefecture income in our 46-prefecture cross-sections. The obvious example is Tokyo. Tokyo specializes in banking and other financial activities, so we expect that many of the deposits in Tokyo banks are not in fact owned by either corporate or household residents of Tokyo. In addition to having relatively large positive values for η_{it}, Tokyo is also the richest prefecture. We propose three ways to purge our estimates of the income elasticity of the effects of the measurement error η_{it}: (1) dropping financial centers from the data set, (2) estimating prefecture fixed effects, and (3) using instrumental variables methods.

5.B.I. Dropping Financial Centers

We suspect that Tokyo, Osaka, and Kanagawa are the most important financial centers in Japan. By dropping these three prefectures, we drop three of the richest and three that we suspect have large positive values for η_{it}. Figure 10 displays cross-prefecture estimates of the income elasticity without the three financial centers and the estimates obtained with all 46 prefectures. A univariate regression does show a large difference between the income elasticity with and without financial centers, however, with conditioning variables, the difference between the two types of estimates are small.

Figure 10 about here

The pooled estimate of the income elasticity without Tokyo, Osaka, and Kanagawa is 1.91 (s.e.=0.043) holding ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant and 1.22 (s.e.=0.056) holding SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant. Compared with the pooled estimate of 1.92 (s.e.=0.06) holding ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant and 1.25 (s.e.=1.25) holding SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant, it appears that the inclusion of Tokyo, Osaka, and Kanagawa keep the estimates of the income elasticity with conditioning variables virtually unchanged.

For two reasons it is not clear that the income elasticity estimate without the three financial centers is superior to that obtained with all 46 prefectures. First, we might suspect that, among the prefectures that are not "financial centers," richer families and larger businesses are more likely to search across prefecture borders for banking services. Richer prefectures might, for example, be more likely to have citizens and firms whose travels to Tokyo or another financial center facilitates banking there. This is a reason why the error term in a money demand equation might be *negatively* correlated with income per capita. Second, the theory tells us that the level of financial technology decreases the demand for money because more transactions services can be obtained for a given money balance. If there is superior financial technology in the richer financial centers, this is yet another reason why the error term in a money demand equation might be *negatively* correlated with income per capita.

5.B.II. Prefecture Fixed Effects

If we suppose that the percentage difference between money held by residents of the prefecture and money deposited in banks of the prefecture, η_{it}, differs across prefectures in a way that might be correlated with income and other variables, but that cross-prefecture differences are constant over time, then the introduction of prefecture fixed effects is the correct way to purge our estimates of the effects of the supply of banking. A pooled regression of log real MF2 per capita on log real income per capita, SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$and sets of year and prefecture dummies, yields an income elasticity of 0.55 (s.e.=0.032). Unlike our previous estimates, this is dramatically less than one.

It is well known that the fixed effect cleans out permanent component of unobservables, and fixed effect estimator picks up short run correlations between dependent and independent variables (see Mairess (1990) for such examples). However, the addition of prefecture fixed effect could induce downward bias to our income elasticity because of the correlation of explanatory variables and transformed residuals if explanatory variables are measured with error. Suppose that our prefecture income has i.i.d measurement errors. This is not such a bad assumption since the method of compiling the data differs across prefectures. Let s assume that we observe $\ln(\text{income})_{it}$, and the relation with true data $n(\text{income})^*_{it}$ is something like

$$\ln(\text{income})_{it} = \ln(\text{income})^*_{it} + \psi_{it} \tag{17}$$

nd ψ_{it} is i.i.d mean zero disturbance. The regression we wish to estimate is quation (8),

$$\ln(\text{Money})^*_{it} = b0 + b1 \ln(\text{income})^*_{it} + b2Z_{it} + e_{it} \tag{18}$$

However we can run regressions something like equation (19),

$$(\ln(\text{Money})^*_{it} + \eta_{it}) = b0 + b1 (\ln(\text{income})^*_{it} - \psi_{it}) + b2Z_{it} + e_{it}. \tag{19}$$

Suppose that η_{it} is constant over time. In this case, even after taking ifference from within mean, we found negative correlation between observable ncome and measurement error and fixed effect approach would bias downward fixed ffect estimator as Griliches and Hausman (1986) has pointed out. Note that ermanent unobservables could also removed by taking first difference of variables. riliches and Hausman (1986) took advantage of the relationship between the fixed ffect estimator and an estimator based on the first differenced data, and resented a formula to compute consistent estimator from these two estimator. ollowing their method, we arrive at a consistent income elasticity estimate of .63 (with s.e.=0.041) holding PSI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$constant. ince the income elasticity with fixed effects is 0.55, the downward bias due to easurement error due to the introduction of fixed effect is 14%. We get a onsistent income elasticity estimate of 0.89 (with s.e.=0.032) holding ln(PD), $n(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant. Since the income elasticity holding ln(PD), $n(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ with fixed effects is 0.78 (s.e.=0.032), the downward ias is 13% in this case. So far we do not find convincing evidence against the fixed effect estimators.

5.B.III. Instrumental Variables Methods

A third way to purge our estimates of the income elasticity of a measurement error that is correlated with income is to search for a variable that is correlated with income but uncorrelated with a prefecture's propensity to attract a high percentage of its deposits from out-of-prefecture depositors. Moreover, the instrument must be uncorrelated with the error term of money demand functions. The instrument that we propose is the ratio of job offers to the number of job applications. We have this measure for each prefecture for each of the dates 1962-90.

The ratio of job offers to applicants is one of the important indicators of labor market conditions, hence it is highly correlated with business conditions and correlated with short run fluctuations of income. Note that most of the job offers recorded in the public employment office are small business, so it does not fully capture the situations of labor market. Banks are unlikely to make job offers in the public employment office, therefore our ratio variable probably does not reflect regional differences in the financial sophistication of banking sector. If the error term of money demand reflects technology shocks in the banking sector, then our instruments are also likely to be uncorrelated with these kinds of shocks. Hence the ratio can be used as an instrument for prefecture income in a money demand equation.

Our instrumental variables estimate (using the job offer ratio, SPI, $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, $\ln(PD)^4$, year dummies and prefecture fixed effects in a first stage regression for log prefecture income per capita and including SPI, $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, $\ln(PD)^4$ and year dummies as second stage regressors) of the income elasticity is 1.47 (s.e.=0.18). When we exclude prefecture fixed effects for both first and second stage regression, estimated income elasticities by instrumental variable methods is 1.07 (s.e=0.19). These can be compared with our OLS estimate (holding SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, $\ln(PD)^4$ and year dummies) of 1.04 (s.e.=0.066) for the same sample period (1962-90).

Throughout the exercise done in this section, we conclude that our mismeasurement of deposits held by prefecture residents cannot explain our finding of an income elasticity that is greater than one. The only way to pull down income elasticities far below one is the introduction of prefecture fixed effects, and so far we do not have good explanation of why the income elasticity obtained from the regression with fixed effects is so low.

5.C. Regression results using the other prefecture monetary aggregates

Our Theoretical analysis (Fujiki and Mulligan (1995)) begins with a production function that takes "money" as an argument. Although our discussion in Fujiki and Mulligan (1995) makes some suggestions as to how the theory can be generalized to allow for a multitude of "monetary" assets, there is still some ambiguity as the empirical definition of money. For this reason, we estimate money demand functions for a variety of assets. In this subsection, we report interesting results of the regressions using different monetary measures.

5.C.I. MF1; Narrower Definition of Money

As we discuss in the previous section, MF1 covers the banks in the urban area, and includes larger proportion of companies and local government deposits, therefore unconditional cross sectional estimates of income elasticity must be substantially higher than the case of MF2 since better companies are likely to operate in the richer regions. As can be seen in figures 11 and table 11, the income elasticity of MF1 obtained from univariate regression are always higher than MF2 counterpart. However, figure 12 shows that as we add conditioning variables, the difference between two elasticities disappears. The addition of SPI increased the gap between income elasticity of MF1 and that of MF2 , however even in this case the magnitude of the income elasticities of MF2 and those of MF1 are almost the same in the 1960s.

Figures 11-13, Tables 14-16 about here

5.C.II. MF3; Broader Measure of Money

The key issue on the comparison of the elasticity of money demand to scale variables obtained from MF3 and those obtained from MF2 is the effect of the differences in the regional composition of the types of financial institutions on the income elasticity. This reflects the regulation of the geographical allocation of financial institutions since the post office and the agricultural and fishery cooperative associations locate more intensively in the rural area. Also, MF3 adds more weight to personal deposits than MF2, since in principle only individuals can make deposits in the agricultural cooperative associations and the post office. As can be seen in Figure 10, unconditional cross sectional income elasticities of MF3 are always lower than those of MF2 (see details in table 11). However, as can be seen in figures 11 and 12, the gap between the MF2 elasticity and MF3 elasticities are pretty small (see table 11 and 12 for details). Major finding from these exercise is that the broader monetary measure without conditioning variables gives us lower income elasticities than the narrower monetary measure. These results are contrary to the original results of Mulligan and Sala-i-Martin (1992). Note that in figure 13, income elasticity of MF3 conditioned on SPI and ln(PD), $\ln(PD)^2$, $\ln(PD)^3$ and $\ln(PD)^4$ were statistically insignificant after 1974.

5.C.III. MFP; Personal Deposit Data

MFP gives us two interesting results. First, as can be seen in Figure 10, for the case of prefecture income, univariate regressions give us stable income elasticity estimates around 0.7-0.8. Pooled regressions with time effects give us an estimate of 0.75, and we cannot reject the null of a temporally constant income elasticity. Figure 11 shows holding the polynominals of ln(PD), the income elasticity of MFP is almost the same as that of MF1 except 1980. However, the addition of SPI to the set of conditioning variables either violate the sign condition of income elasticities or give us insignificant income elasticities (see for example, the fourth column of table 12 reports the results of regression with SPI). This is not surprising since SPI did not do a good job after 1980. Second, since MFP and MF3 covers almost the same financial institutions, the difference in the income elasticities estimated from those two will reflect the differences in the monetary measure with and without cooperate and local government deposits. Table 11 and table 12 show that income elasticities of MFP are always lower than MF3 counterparts, which leads us to the conclusion that the cooperates and local governments could better be distinguished in the analysis of money demand. Aggregate time series studies may have suffered from this problem as well as the problems listed in the previous section.

6. Extensions

We have documented the stability of cross sectional income elasticities in section 5. Hence, we discuss how we can benefit from our stable cross sectional estimates. We show two applications.

6.A. Recovering the Interest Elasticity

Lucas (1988) argued that in the cash in advance economy, with homothetic preferences, the equilibrium condition gives the same form of the standard money demand function which used consumption instead of income and the scale variable elasticity is one. Poole (1988) expressed his dissatisfaction on time series estimates of income elasticity and he assumed an income elasticity of one. Although Poole (1988) and Lucas (1988) assumed that the income elasticity of M2 was one, we can use the income elasticity estimated from the cross section data since Fujiki and Mulligan (1995) suggests that cross sectional estimates are valid for aggregate per capita time series. Define

$$\text{Lucas residual} = \ln(\text{M2 per capita/CPI}) - \varepsilon_y \cdot \ln(\text{GNP per capita/CPI}), \qquad (20)$$

where ε_y is income elasticity of money demand. We see in table 10 that our best estimates of ε_y are between 1.2 and 1.4, and we know some part of the Lucas residual be explained by interest rate movements. Let us recover the interest rate elasticity by regressing the Lucas residual on an interest rate. More specifically, we use a long term bond rate, the annual yield on five year interest bearing bank debentures to make our results comparable to the results in table 1. We pick two income elasticities 1.384 (holding SPI, ln(PD), $\ln(PD)^2$ constant) and 1.222 (holding SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, $\ln(PD)^4$ constant) from table 10. Table 14 shows the results of regressing the lucas residual on a long term interest rate. Since some readers might suspect the plausibility of the effect of interest rate movements on money demand in early periods of our sample due to the interest rate regulation in Japan, we report our results of estimation using whole 1955-90 sample, 1975-90 sample and 1980-90 sample.

Table 17 about here

Table 14 suggests that the magnitude of our estimates of interest rate elasticities are more than 0.2, and took on the value of -0.2 to -0.3 if we drop the samples of earlier days. These estimates have larger magnitudes than the time series estimates obtained from the level regressions in table 1.

6.B. Recovering technical progress from long run pooling regressions

The other interesting exercise is to recover technical progress of cash management technology. Let us think about a simple model of transaction technology of prefecture i at time t,

$$(\text{Money stock}_{it}) = \alpha_t (\text{Scale variable}_{it})^{\beta_t} \tag{21}$$

Our cross sectional univariate model is the same as this model at a certain time. Based on the results of the previous section, we suspect that the cross sectional income elasticities are stable over time. Hence it is natural to think that α_t captures the effect of interest rate and technical progress in a sense that α_t decreases over time. In the final part of 5.A.III we find pooling regression for MF2 cannot support the hypothesis of the shift of the intercept term after 1985. We think that MF1 would be the most relevant monetary measure to examine the implications of this model, since MF1 would be likely to reflect the effect of the changes in the financial sophistication more than MF2 would do, and take prefecture income as scale variable. Figure 14 is our time effect obtained from the pooling regression of log MF1 on prefecture income, SPI, $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant and $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant using 1960-1990 sample. We regress these estimates of the time effects on a constant term and an interest rate, and obtained the residuals. Here we use a short term interest rate (overnight call rate) as the relevant opportunity cost of MF1. Since time effect captures aggregate shock at one time holding income constant, and if we clean out the effect of interest rate, the residual must reflect the neutral technical progress of transaction technology common to all regions. We find steady reduction of residuals, or the evidence of technical progress in the transaction technology from 1960 to 1990, particularly in 1960s, in figure 15.

Figure 14 and 15 about here

7. Summary and Policy implication

Stability of the Income Elasticity Obtained from Cross Sections

We find that our cross sectional estimates of income elasticities with conditioning variable are stable over time in the case of MF1, MF2 or MF3. In particular, our best estimates of income elasticity of our counterpart of M2-Cash are 1.2-1.4. We also find that MFP yields a stable income elasticity of about 0.75 without conditioning variables. We take advantage of the stable income elasticities obtained from cross sectional estimates, and extend the analysis of Lucas (1988) to obtain the interest rate elasticities from aggregate time series data. Our estimates of interest rate elasticity based on our finding of income elasticity of 1.2 - 1.4 are -0.2 ~ -0.3 for real M2 per capita. We achieve a nice division of labor between cross section data and time series data based on our theory: cross section data gives us the situation of holding interest rates (and other prices) constant, and time series data allow us to see the effects of interest rates.

Several papers examine the shift of money demand functions using time series models, typically checking if the fit of money demand function becomes worse in the

80s or not. According to our cross sectional estimation, our income elasticities for MF2, MF3 and MFP are remarkably stable. In particular, the stability of the MFP income elasticity seems to tell us that if we ever observe the fluctuations of money demand observed in the time series models, that could be the result of the changes in the cash management technology of cooperate sector and local government, not by the households. We show that our approach can get the information of the technical progress from the time effect of pooling regression, since our income elasticities are stable. People casually claim that financial sophistication means they need to leave a smaller part of their income in their banks. But they do not explicitly say whether the financial innovation can be captured by the income elasticities (slope effect) or the time effect (intercept effect), or both (money demand shifts every year). If we ever believe there is financial innovation, we must look at intercept term since we know slope term has been stable.

Consistency with Other Studies of the Demand for Money

We find the income elasticity of the demand for something like M2 minus currency to be 1.2-1.4. Given our arguments about the validity of the identifying restrictions required to obtain consistent estimates of the structural parameters, our findings are consistent with a variety of findings from other data sets. For example, Yoshida and Rasche (1990) found equilibrium income elasticity of M2 to be 1.2 using time series data from 1956 to 1985, Rasche (1990) found Japanese M1 income elasticity was 1.0. Using U.S. time data for the period 1874-1975, Friedman and Schwartz found a gross M2 income elasticity of 1.2. Lucas (1988) and Meltzer (1963) found a gross M1 income elasticity of 1.0, but an potentially important source of bias in their findings is the rapid improvements in financial technology which occurred since World War II. This is consistent with the pattern of our annual estimates of the level of financial technology reported in Figure 14. Although we estimate a gross scale elasticity of the demand for money, our estimates are not inconsistent with some kind of scale economies in the holding of money such as those proposed by Baumol (1952) and Tobin (1956).[27]

Policy Implications

Our finding that we have stable income elasticities leads to several strong implications for the money targeting rules. First, our results suggested that the scale elasticity may be stable but not 1. Friedman's k % rule assumes that money and income grows at the same speed, hence a primitive k% rule might not be attractive. Second, when a central bank looks carefully at the velocity as one of the important indicator, our findings leads to a natural guide line for the trend of velocity. If the income elasticity of money demand is 1.2-1.4, we see the secular decline of velocity in Japanese M2 is explained by the growth of real income. Our theory predicts holding interest rates and the level of financial technology constant, one percent of real income growth reduces velocity by 0.2-0.4 percent. Third, when the central bankers want to control the level of money stock using the interest rate as an instrument, the precision of control crucially depends on the accuracy of the income elasticity. Suppose central bankers want to keep the level of money stock at the level of M^* under the expectation of P^* of price level, y^* of income level. Suppose they use money demand function of the form of $M = P + a1y + a2R + e$ where e is error term to and set the interest rate at R^* so that they can achieve target value of money stock. In this case, the mean square error of the control is,

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[27]See, for example, the discussions in Karni (1973) and Mulligan (1994).

$$
\begin{aligned}
E(M-M^*) &= (P-P^*) + a1(y-y^*) + a2(R^*-R^*) + e \\
&= (P-P^*) + a1(y-y^*) + e.
\end{aligned}
$$

where $E(\cdot)$ is the operator of expected value. Hence controllablity measured by the mean square error when the central bank's estimates of money demand function keeps track with money demand reasonably well is

$$E\Big[(P-P^*) + a1(y-y^*) + e\Big]^2$$

which depends not only the central bank's forecast error of y and P, but also on the income elasticity a1. Therefore, central bankers can benefit from our estimates of stable income elasticity.

Future Challenge

Our strategy may not be attractive for the central bankers worrying about the implementation of monetary policy for the immediate future since the prefecture income data are published three years after the quick estimates of aggregate GNP data and our approach does not say much about the effect of short run interest rate fluctuations on the money supply. A further challenge is the discovery of the stable relationship between household survey and MF1, since MF1 is available monthly. Based on these estimates, we can figure out the relevant interest rate elasticity as we did in section 6. Once this can be done, our approach may even help the central bankers.

Data Sources Appendix

Japanese M2: *Economic Statistics Annual,* The Bank of Japan, various issues.

Japanese Interest rate of interest bearing bank debentures five years maturity: *Economic Statistics Annual,* The Bank of Japan, various issues.

Japanese Interest rate of call rate, over night, collateralized, average within periods, median of offer rate: *Economic Statistics Annual,* The Bank of Japan, various issues.

Japanese GNP: *Economic Statistics Annual,* The Bank of Japan, various issues.

MF1: *Prefecture Economic Statistics*, The Bank of Japan, various issues.

MF2: *Prefecture Economic Statistics*, The Bank of Japan, various issues.

MF3: *Prefecture Economic Statistics*, The Bank of Japan, various issues.

MFP: *Prefecture Economic Statistics*, The Bank of Japan, various issues.

Population: *Prefecture Economic Statistics*, The Bank of Japan, various issues.

Area size: *Prefecture Economic Statistics*, The Bank of Japan, various issues.

Prefecture income: *Kenmin Keizai Keisan,* Economic Planning Agency, various issues.

Employee income: *Kenmin Keizai Keisan,* Economic Planning Agency, various issues.

Consumption: *Kenmin Keizai Keisan,* Economic Planning Agency, various issues.

Regional consumer price difference index: *Prefecture Economic Statistics*, The Bank of Japan, various issues.

CPI Tokyo 1934-36=100 index: *Historical Statistics of Japanese Economy*, The Bank of Japan.

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Table 1.--- Time series estimates of the income elasticity

Equation form	Income elasticity	Interest elasticity	Adj. R-2 (D.W.)
log level, call rate	1.476	-0.039	0.9932
	(0.018)	(0.012)	(0.164)
log level, bond rate	1.454	-0.079	0.9935
	(0.022)	(0.022)	(0.176)
	1.4929		0.9927
	(0.016)		(0.153)
log level with trend	1.224	-0.033	0.9937
call rate	(0.125)	(0.014)	(0.145)
log level with trend	1.259	-0.061	0.9937
bond rate	(0.131)	(0.026)	(0.156)
	1.196		0.9933
	(0.126)		(0.1357)
log, differenced	1.011	-2.247	
call rate, no constant	(0.110)	(1.125)	(1.403)
log, differenced	1.017	-2.376	
bond rate, no constant	(0.110)	(1.811)	(1.437)
	1.012		
	(0.112)		(1.394)
log, differenced	0.5871	-1.878	0.1996
call rate, with constant	(0.1359)	(1.107)	(1.017)
log, differenced	0.5912	-1.111	0.1818
bond rate, with constant	(0.1399)	(1.641)	(0.954)
	0.5784		0.1860
	(0.136)		(0.947)

Numbers in parenthesis are standard error of the estimates a la White. Estimated sample periods are 1967:3Q-1993:1Q.
Data: M2CD, seasonally adjusted, average stock within quarter. GNP, seasonally adjusted. Call rate. overnight, collateralized, average within periods, median of offer rate. Bond rate. Annual yield of five year interest bearing bank debentures.

Table 2.---Summary of Japanese monetary aggregates as of March 31 1990.

	(100 million yen)	% to M2+CD
Cash	333,385	7.05
M1	1,220,270	25.82
M2	4,606,152	97.48
CDs	118,626	2.51
M2+CD	4,724,778	100.00
M3+CD	7,490,195	158.53

Sources: *Economic Statistics Annual, The Bank of Japan* 1990, p.18

Table 3.---Summary of Japanese deposits as of March 31 1990 (100 million yen)

	Deposits Total	% to total
"All banks"		
City banks	1,920,467	27.01
Regional banks	1,497,686	21.07
Regional banks 2	548,401	7.71
Trust banks	146,770	2.06
Long term credit banks	82,480	1.16
Community banks	749,094	10.53
Shokochukin bank	24,599	0.34
Credit cooperatives	198,616	2.79
Labor credit association	65,660	0.92
Agricultural cooperatives	509,881	7.17
Fishery co-operatives	18,583	0.26
Post office	134,722	18.93
Total	7,107,959	100.00

Sources: *Economic Statistics Annual, The Bank of Japan* 1990

Table 4.---Summary of Japanese deposits as of March 31 1990 (100 million yen)

	Total "All banks"	% to total
Total	4,195,805	100.00
Demand deposits		
Current	267,129	6.36
Ordinary	619,773	14.77
Notice	156,829	3.73
Special	83,431	1.98
Tax payment	2,387	0.05
Saving deposits		
Time	2,649,761	63.15
Installment	43,342	1.03
Others	373,144	8.89

Sources: *Economic Statistics Annual, The Bank of Japan* 1990, p.46
Note: These numbers are taken from the balance sheet of banks.

Table 5.---Summary table of MFs as of March 1990.

	(100 million yen)	% to MF2
(1) MF1	977,432	21.24
(2) "All banks" total	3,824,343	87.17
(3) Community banks	749,373	16.28
(4) Shokochukin banks	24,514	0.53
(5) MF2((2)+(3)+(4))	4,598,230	100.00
(6) Credit cooperatives	196,806	4.27
(7) Agriculture and Fishery Cooperatives	527,040	11.45
(8) Labor Credit Associations	64,913	1.40
(9) Post office	1,340,780	29.14
(10) MF3 (5)+(6)+(7)+(8)+(9)	6,727,769	146.32

Note: We dropped the data for Okinawa prefecture.

Table 6.---Coverage of financial institutions in the Aggregate data and MFs

Financial institutions	M1	M2	M3	MF1	MF2	MF3
"All banks" (Demand deposit)	yes	yes	yes	yes	yes	yes
(Saving deposit)		yes	yes		yes	yes
Community banks (Demand deposit)	yes	yes	yes		yes	yes
(Saving deposit)		yes	yes		yes	
Shokochukin banks	yes	yes	yes		yes	yes
Credit cooperatives			yes			yes
Agriculture and Fishery Cooperatives			yes			yes
Labor Credit Associations			yes			yes
Post office			yes			yes

Table 7.--- Summary table of MFP as of March 1990.

	(100 million yen)	% to total
MFP total	4,348,369	100.00
"All banks"	1,769,019	40.68
Community banks	518,392	11.92
Credit cooperatives	133,050	3.05
Agriculture and Fishery Cooperatives	519,643	11.95
Labor Credit Associations	63,495	1.46
Post office	1,344,770	30.92

Note: We dropped the data for Okinawa prefecture.

Table 8.----Regression results
(Univariate Regression)

Sample	Coefficient on ln(income)	R-2
1955	2.424 (0.171)	0.819
1960	2.073 (0.140)	0.832
1965	2.227 (0.192)	0.753
1970	1.958 (0.143)	0.808
1975	2.565 (0.309)	0.609
1980	2.182 (0.302)	0.542
1985	1.973 (0.265)	0.556
1990	2.076 (0.256)	0.599
1955-1990	2.155 (0.032)	0.947

Note; Numbers in the parenthesis are standard error of estimators. All regressions included constant term or time effect, which are not reported here. F value for the test of constancy of income elasticity = 0.952. Figure 4 plots above estimators.

Table.9----The results of pooling regressions holding constant polynomials of ln(PD). Dependent variable ln(MF2/CPI) per capita.

List of explanatory Variables					
Income	ln(PD)	$\ln(PD)^2$	$\ln(PD)^3$	$\ln(PD)^4$	R-2 (F)
2.155 (0.032)					0.947 (0.95)
1.977 (0.046)	0.043 (0.008)				0.948 (0.69)
1.932 (0.046)	0.080 (0.010)	0.026 (0.004)			0.949 (0.52)
1.985 (0.058)	-0.016 (0.011)	0.110 (0.007)	0.047 (0.003)		0.955 (0.55)
1.916 (0.043)	-0.193 (0.019)	0.049 (0.008)	0.132 (0.008)	0.033 (0.002)	0.958 (0.67)

Note; sample periods are 1955-90. Numbers in the parenthesis are standard error of estimators. (F) show the F-value of null hypothesis that the cross sectional income elasticities are constant over the sample periods. These F values are too small to reject the null hypothesis of constant income elasticity over 1955-90.

Table 10.----The results of pooling regressions holding constant SPI and polynomials of ln(PD). Dependent variable ln(MF2/CPI) per capita.

List of explanatory Variables						
						R-2
Income	SPI	ln(PD)	$ln(PD)^2$	$ln(PD)^3$	$ln(PD)^4$	(F)
1.678 (0.057)	-0.014 (0.001)					0.950 (0.63)
1.597 (0.061)	-0.013 (0.001)	0.027 (0.008)				0.951 (0.51)
1.384 (0.063)	-0.017 (0.001)	0.083 (0.009)	0.043 (0.004)			0.954 (0.43)
1.284 (0.058)	-0.023 (0.001)	-0.037 (0.011)	0.015 (0.007)	0.059 (0.003)		0.961 (0.46)
1.222 (0.056)	-0.023 (0.001)	-0.210 (0.018)	0.094 (0.008)	0.142 (0.007)	0.032 (0.002)	0.965 (0.62)

Note; sample periods are 1955-90. Numbers in the parenthesis are standard error of estimators. (F) show the F-value of null hypothesis that the cross sectional income elasticities are constant over the sample periods. These F values are too small to reject the null hypothesis of constant income elasticity over 1955-90.

Table 11.----The results of univariate regressions using different scale variables (Dependent variable: MF2)

Scale variable	Prefecture Income		Consumption		Employee Income	
Year	Coefficient ln(Scale)	R-2	Coefficient ln(Scale)	R-2	Coefficient ln(Scale)	R-2
1955	2.424 (0.17)	0.81			1.309 (0.11)	0.74
1960	2.073 (0.14)	0.83			1.423 (0.12)	0.74
1965	2.227 (0.19)	0.75	2.903 (0.36)	0.58	1.533 (0.15)	0.69
1970	1.958 (0.14)	0.80	3.008 (0.29)	0.70	1.350 (0.16)	0.59
1975	2.565 (0.30)	0.60	2.759 (0.50)	0.40	1.659 (0.25)	0.48
1980	2.182 (0.30)	0.54	2.913 (0.50)	0.42	1.602 (0.29)	0.40
1985	1.973 (0.26)	0.55	2.727 (0.50)	0.39	1.499 (0.25)	0.43
1990	2.076 (0.25)	0.59	2.389 (0.52)	0.31	1.616 (0.26)	0.45

Note: Figure 7 plots plots estimators for every year.
All regressions include constant term which are not reported here.

Table 12.----The results of regressions holding ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant (Dependent variable: MF2)

Scale variable	Prefecture Income		Consumption		Employee Income	
Year	Coefficient ln(Scale)	R-2	Coefficient ln(Scale)	R-2	Coefficient ln(Scale)	R-2
1955	2.221 (0.30)	0.82			1.201 (0.17)	0.81
1960	2.140 (0.22)	0.85			1.449 (0.18)	0.81
1965	2.107 (0.31)	0.79	2.389 (0.54)	0.70	1.460 (0.23)	0.77
1970	1.849 (0.20)	0.86	2.428 (0.38)	0.79	1.159 (0.21)	0.75
1975	1.622 (0.44)	0.72	1.666 (0.45)	0.72	1.013 (0.32)	0.70
1980	1.263 (0.39)	0.70	1.575 (0.45)	0.71	0.786 (0.36)	0.66
1985	1.210 (0.37)	0.68	1.527 (0.46)	0.68	0.837 (0.32)	0.66
1990	1.250 (0.33)	0.73	1.023 (0.48)	0.68	0.876 (0.31)	0.70

Note: Figure 8 plots plots estimators for every year.
All regressions include constant term, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ which are not reported here.

Table 13.----The results of regressions holding SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant (Dependent variable: MF2)

Scale variable	Prefecture Income		Consumption		Employee Income	
Year	Coefficient ln(Scale)	R-2	Coefficient ln(Scale)	R-2	Coefficient ln(Scale)	R-2
1955	1.551 (0.29)	0.88			0.743 (0.23)	0.84
1960	1.527 (0.29)	0.87			0.913 (0.33)	0.83
1965	1.155 (0.37)	0.84	0.566 (0.58)	0.81	0.459 (0.41)	0.81
1970	1.505 (0.29)	0.87	1.450 (0.48)	0.82	0.489 (0.29)	0.80
1975	0.601 (0.42)	0.81	0.838 (0.40)	0.82	-0.310 (0.38)	0.80
1980	0.468 (0.46)	0.75	0.937 (0.46)	0.76	-0.481 (0.47)	0.75
1985	0.389 (0.50)	0.72	0.926 (0.47)	0.74	-0.167 (0.45)	0.72
1990	0.553 (0.40)	0.77	0.261 (0.46)	0.76	0.053 (0.38)	0.76

Note: Figure 9 plots plots estimators for every year.

All regressions include constant term, SPI, ln(PD), $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ which are not reported here.

Table 14.----The results of univariate regression using different monetary measure

Year	MF1 Coefficient ln(income)	R-2	MF2 Coefficient ln(income)	R-2	MF3 Coefficient ln(income)	R-2	MFP Coefficient ln(income)	R-2
1955			2.424 (0.17)	0.81	2.079 (0.14)	0.82		
1960	2.836(0.19)	0.82	2.073 (0.14)	0.83	1.767 (0.11)	0.83		
1965	3.193(0.25)	0.77	2.227 (0.19)	0.75	1.740 (0.16)	0.71		
1970	2.769(0.19)	0.82	1.958 (0.14)	0.80	1.445 (0.12)	0.75		
1975	3.614(0.33)	0.72	2.565 (0.30)	0.60	1.637 (0.25)	0.48		
1980	3.039(0.36)	0.61	2.182 (0.30)	0.54	1.278 (0.26)	0.34	0.722 (0.23)	0.18
1985	2.551(0.31)	0.60	1.973 (0.26)	0.55	1.164 (0.24)	0.33	0.726 (0.21)	0.20
1990	2.086(0.25)	0.60	2.076 (0.25)	0.59	1.198 (0.23)	0.36	0.742 (0.20)	0.23

Note: Figure 11 plots estimators for every year. All of the regressions include constant term which are not reported here.

Table 15.----The results of regression using different monetary measure, holding $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ constant

Year	MF1 Coefficient ln(income)	R-2	MF2 Coefficient ln(income)	R-2	MF3 Coefficient ln(income)	R-2	MFP Coefficient ln(income)	R-2
1955			1.614 (0.31)	0.86	1.672 (0.27)	0.84		
1960	2.187(0.41)	0.82	1.568 (0.32)	0.85	1.541 (0.27)	0.84		
1965	1.894(0.24)	0.89	1.328 (0.42)	0.79	1.925 (0.26)	0.77		
1970	1.858(0.37)	0.88	1.778 (0.33)	0.82	1.608 (0.17)	0.76		
1975	1.689(0.37)	0.88	0.917 (0.49)	0.72	1.259 (0.36)	0.63		
1980	1.181(0.36)	0.85	0.836 (0.52)	0.63	1.077 (0.36)	0.54	0.859 (0.33)	0.36
1985	0.940(0.33)	0.83	0.988 (0.56)	0.60	1.057 (0.35)	0.41	0.915 (0.31)	0.38
1990	0.680(0.24)	0.85	0.924 (0.47)	0.66	0.968 (0.32)	0.54	0.767 (0.29)	0.40

Note: Figure 12 plots above estimators for MF1, MF2 and MF3 every year intervals. All regressions contains constant term and $\ln(PD)$, $\ln(PD)^2$, $\ln(PD)^3$, and $\ln(PD)^4$ which are not reported here.

Table 16.----The results of regression using different monetary measure, holding SPI, ln(PD), $ln(PD)^2$, $ln(PD)^3$, and $ln(PD)^4$constant

Year	MF1 Coefficient ln(income)	R-2	MF2 Coefficient ln(income)	R-2	MF3 Coefficient ln(income)	R-2	MFP Coefficient ln(income)	R-2
1955			1.551 (0.29)	0.88	2.094 (0.24)	0.83		
1960	1.385(0.40)	0.88	1.527 (0.29)	0.87	1.497 (0.24)	0.88		
1965	1.065(0.50)	0.86	1.155 (0.37)	0.84	1.291 (0.33)	0.81		
1970	1.630(0.36)	0.90	1.505 (0.29)	0.87	1.455 (0.25)	0.83		
1975	1.202(0.42)	0.89	0.601 (0.42)	0.81	0.329 (0.37)	0.78		
1980	0.855(0.46)	0.85	0.468 (0.46)	0.75	0.324 (0.42)	0.62	0.071 (0.38)	0.50
1985	0.590(0.48)	0.83	0.389 (0.50)	0.72	-0.004 (0.46)	0.60	-0.128 (0.39)	0.54
1990	0.632(0.32)	0.85	0.553 (0.40)	0.77	0.197 (0.38)	0.85	0.041 (0.34)	0.53

Note: Figure 13 plots above estimators for MF1, MF2 and MF3 every year intervals. All regressions contains constant term and SPI, ln(PD), $ln(PD)^2$, $ln(PD)^3$, and $ln(PD)^4$ which are not reported here.

Table 17.----The results of estimated interest rate elasticity

Sample periods	$\varepsilon_y = 1.384$	$\varepsilon_y = 1.222$
1956-1990	-0.161 (0.074)	-0.374 (0.075)
1975-1990	-0.199 (0.051)	-0.282 (0.068)
1980-1990	-0.201 (0.060)	-0.265 (0.079)

Note; Numbers in the parenthesis are standard error of estimators. Estimated equations are $\{\ln(MF2) - \varepsilon_y \ln(\text{income})\}$ on constant and ln(interest rate).

Fig.1 Dispersions of real prefecture money per capita

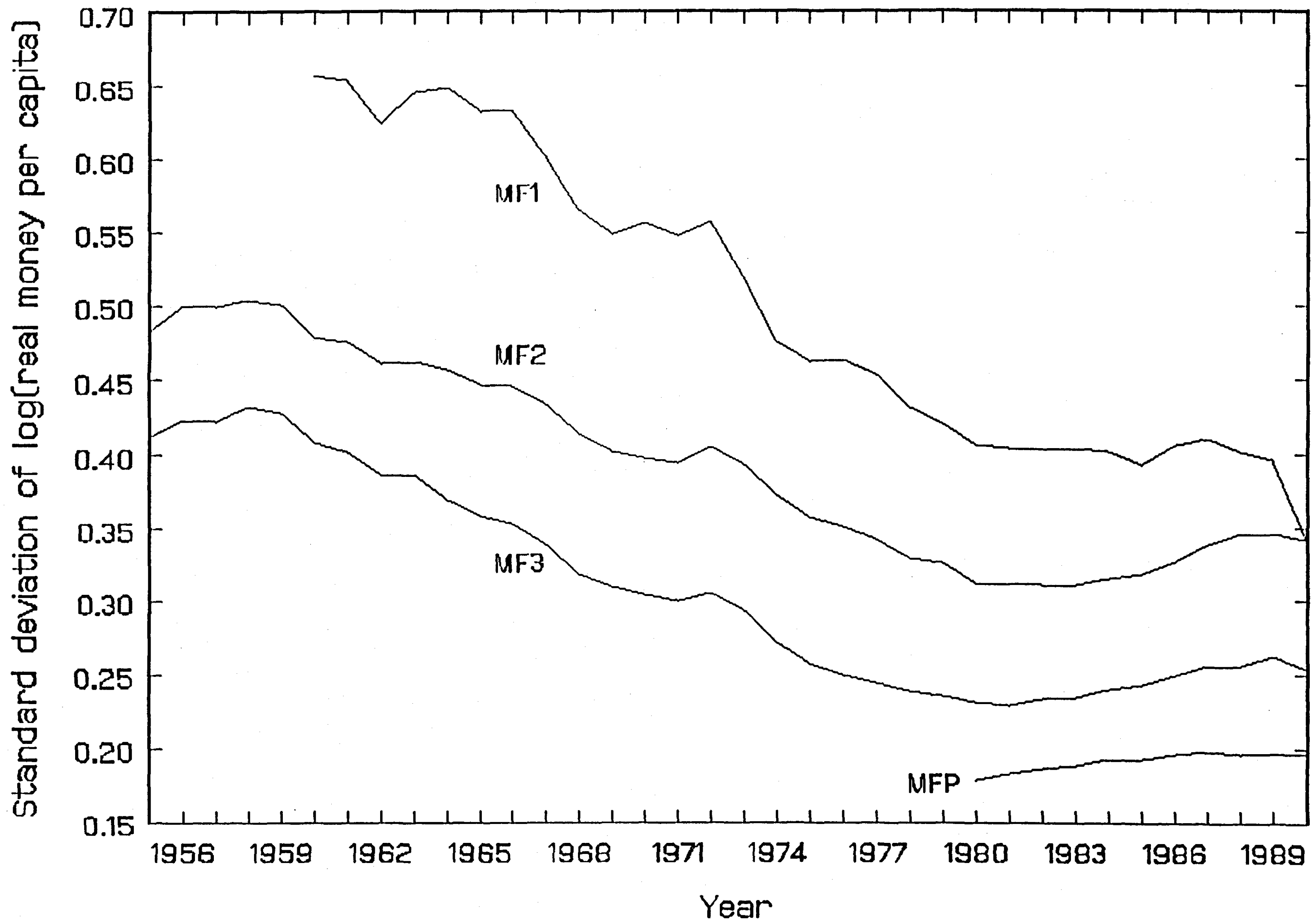

Fig.2. Dispersions of prefecture real scale variable per capita

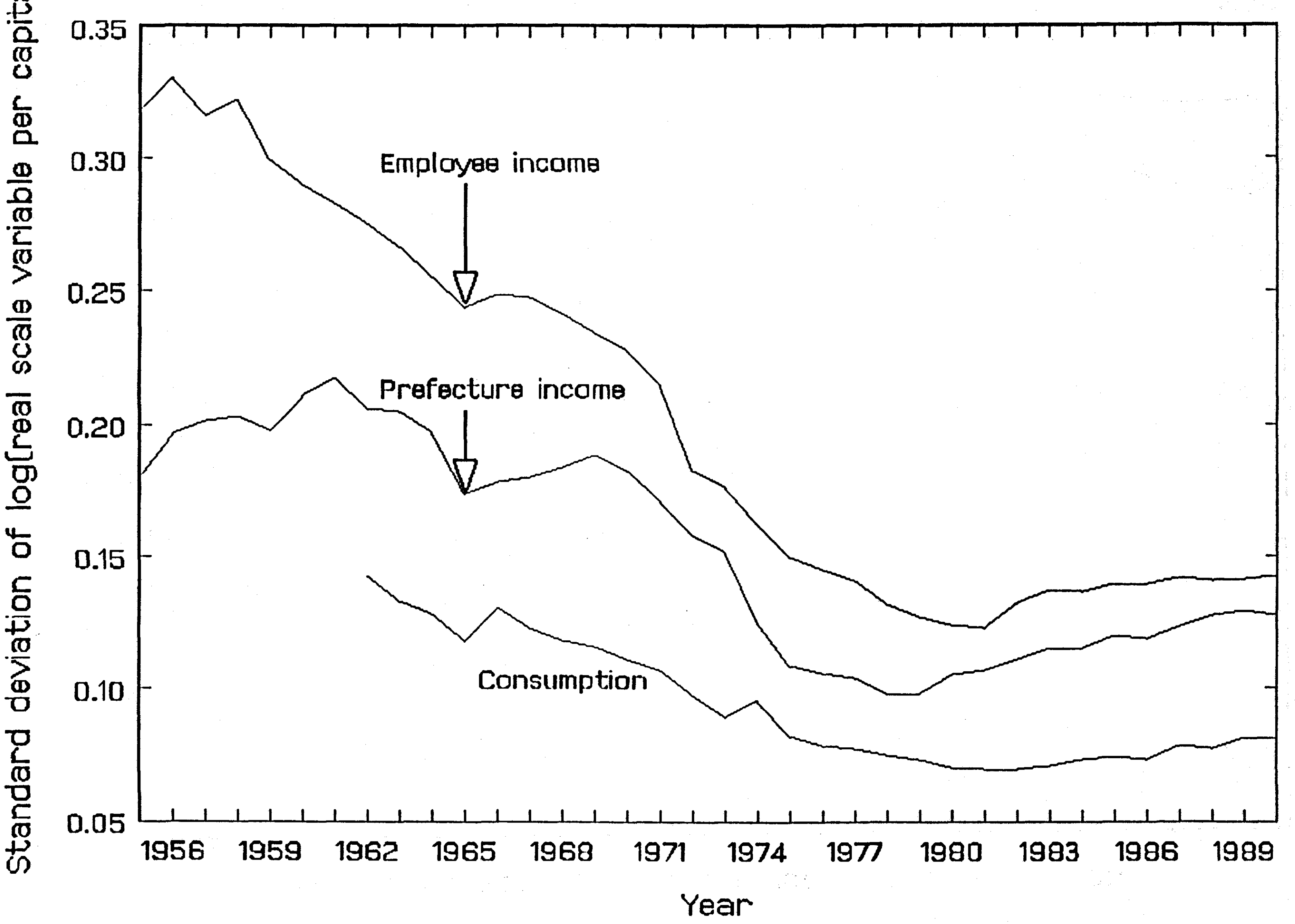

Fig.3. Dispersions of prefecture money velocity

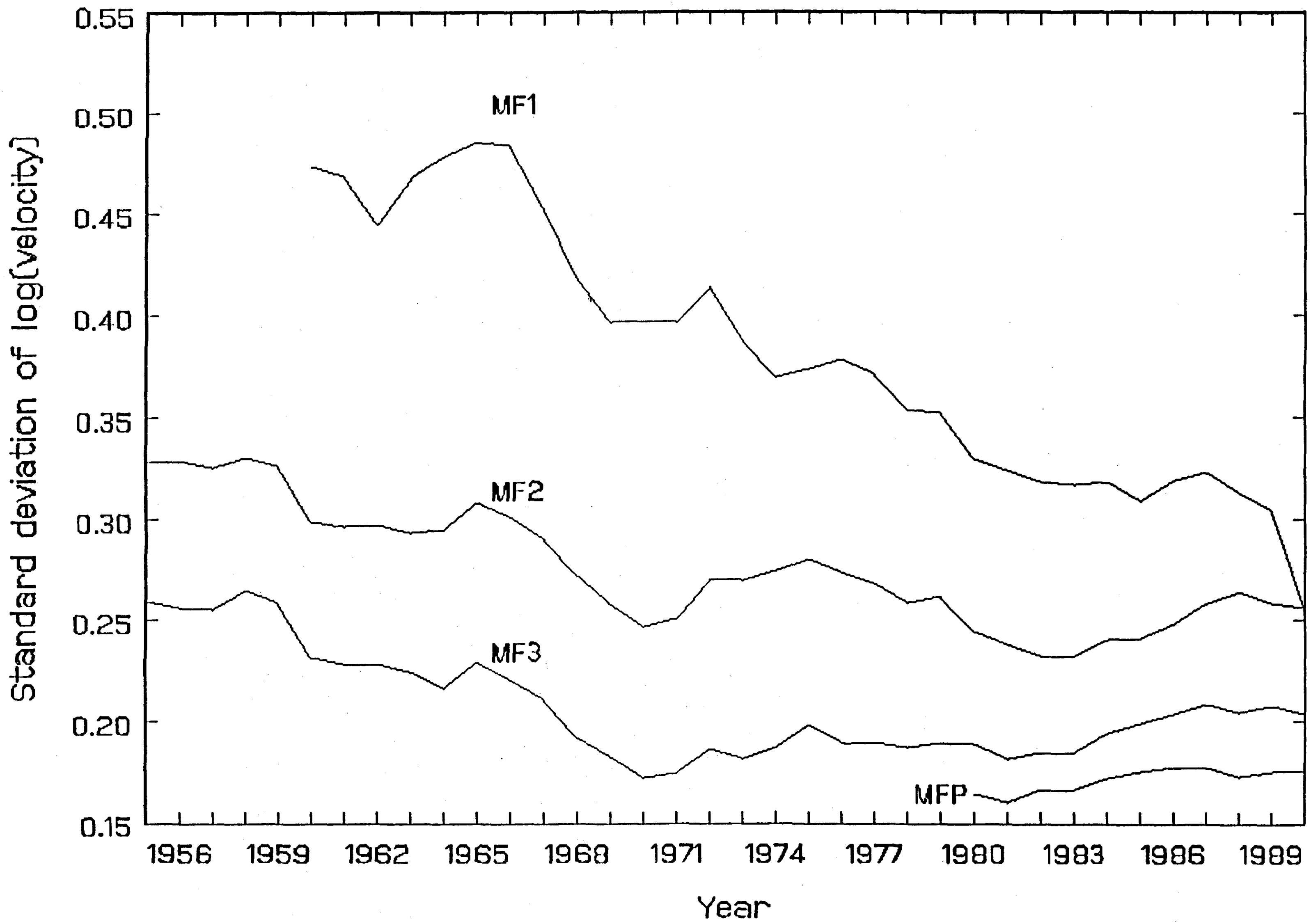

Fig.4. Cross Sectional Prefecture Income Elasticity of MF2

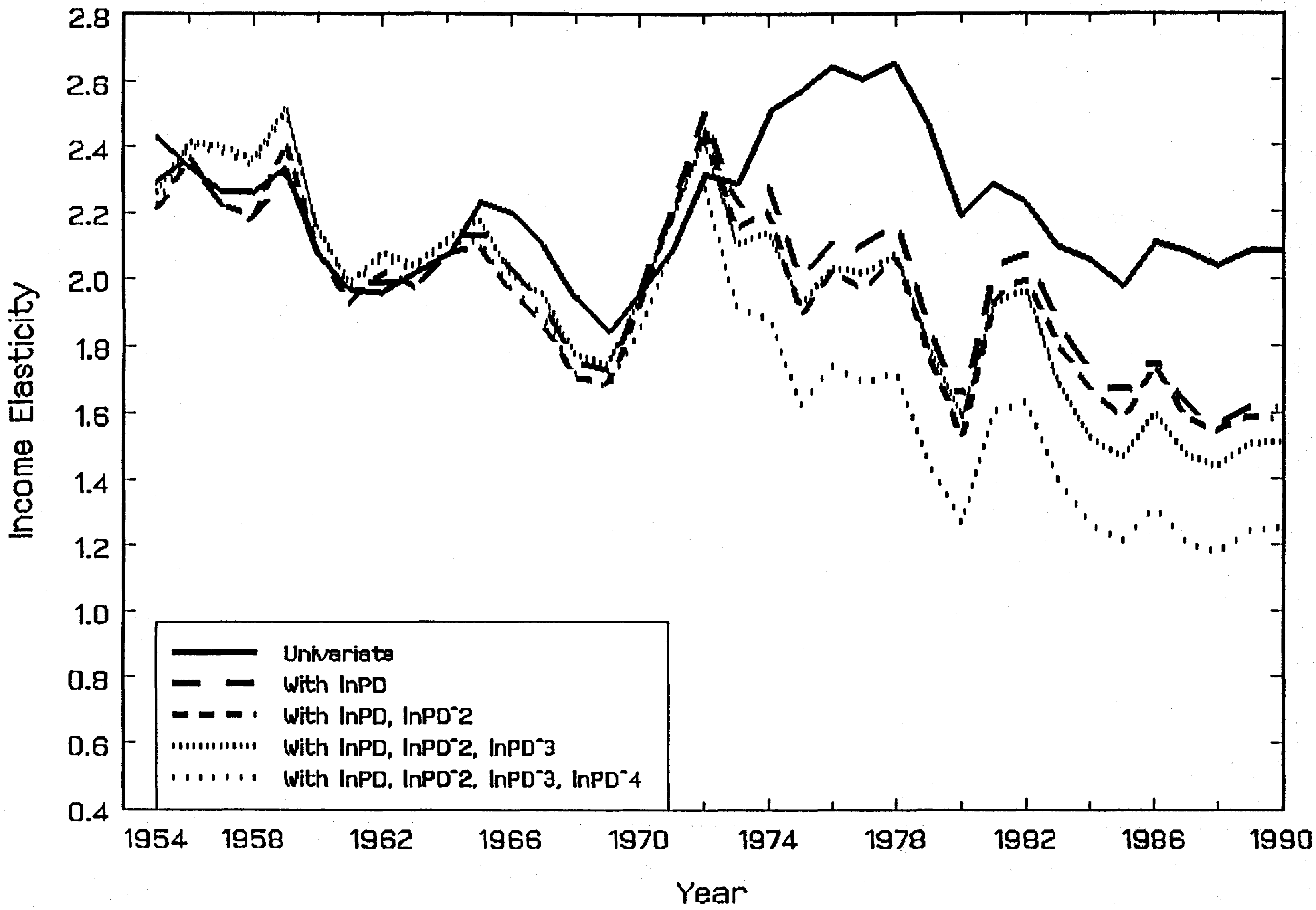

Fig.5. Cross Sectional Prefecture Income Elasticity of MF2

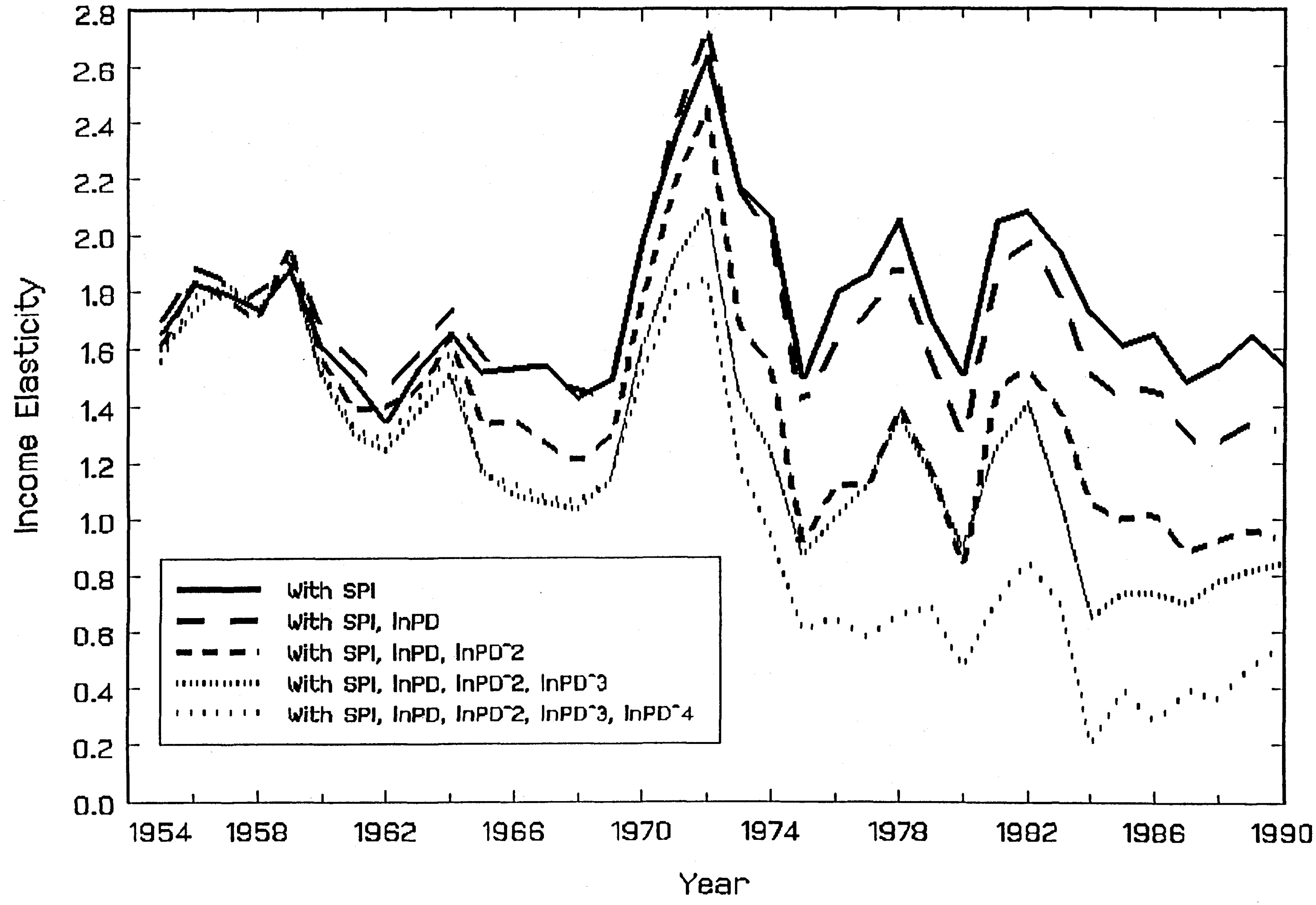

Fig.6. Cross Sectional Prefecture Income Elasticity of MF2

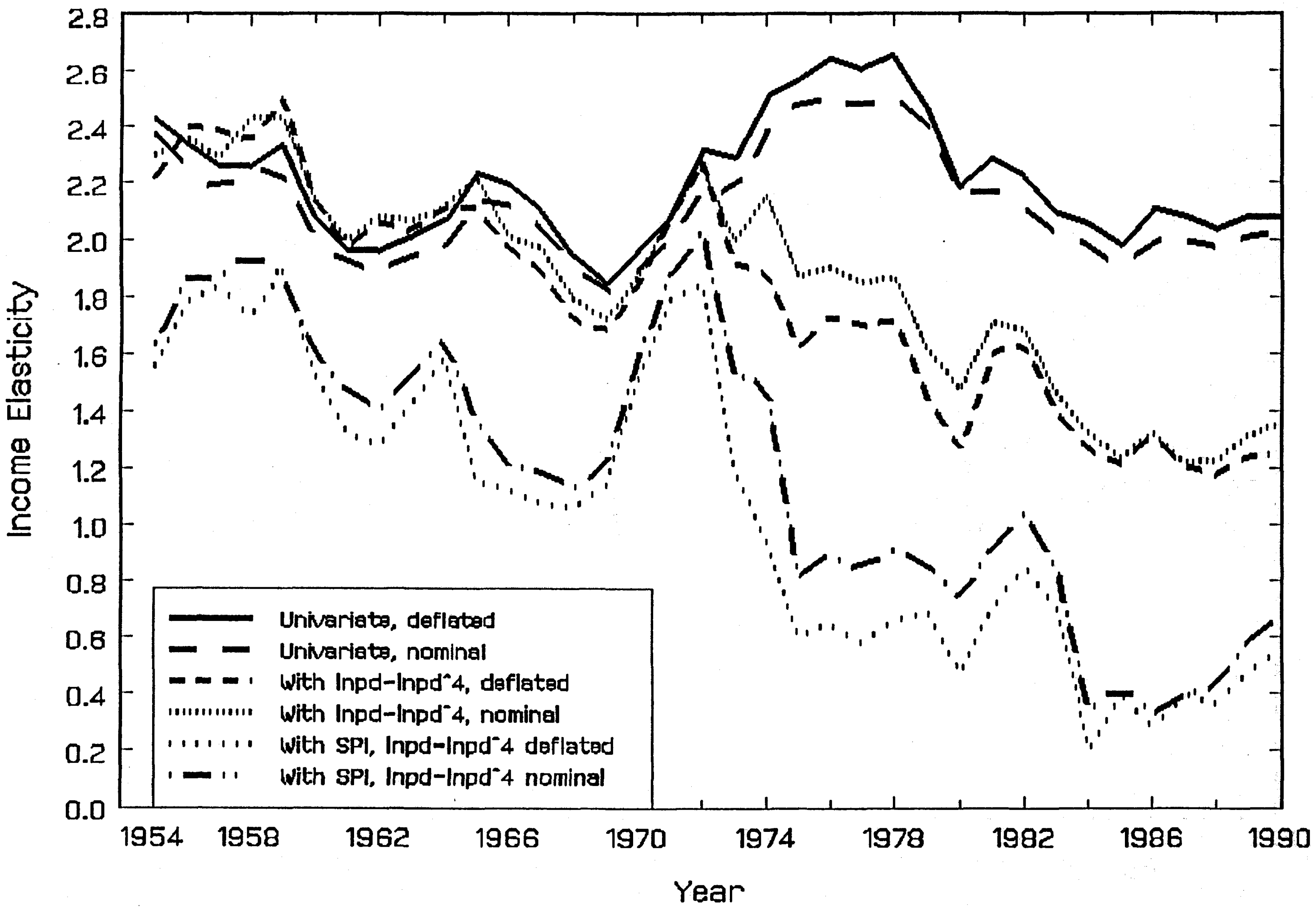

Fig.7. Choice of scale variables (use MF2, Univariate form)

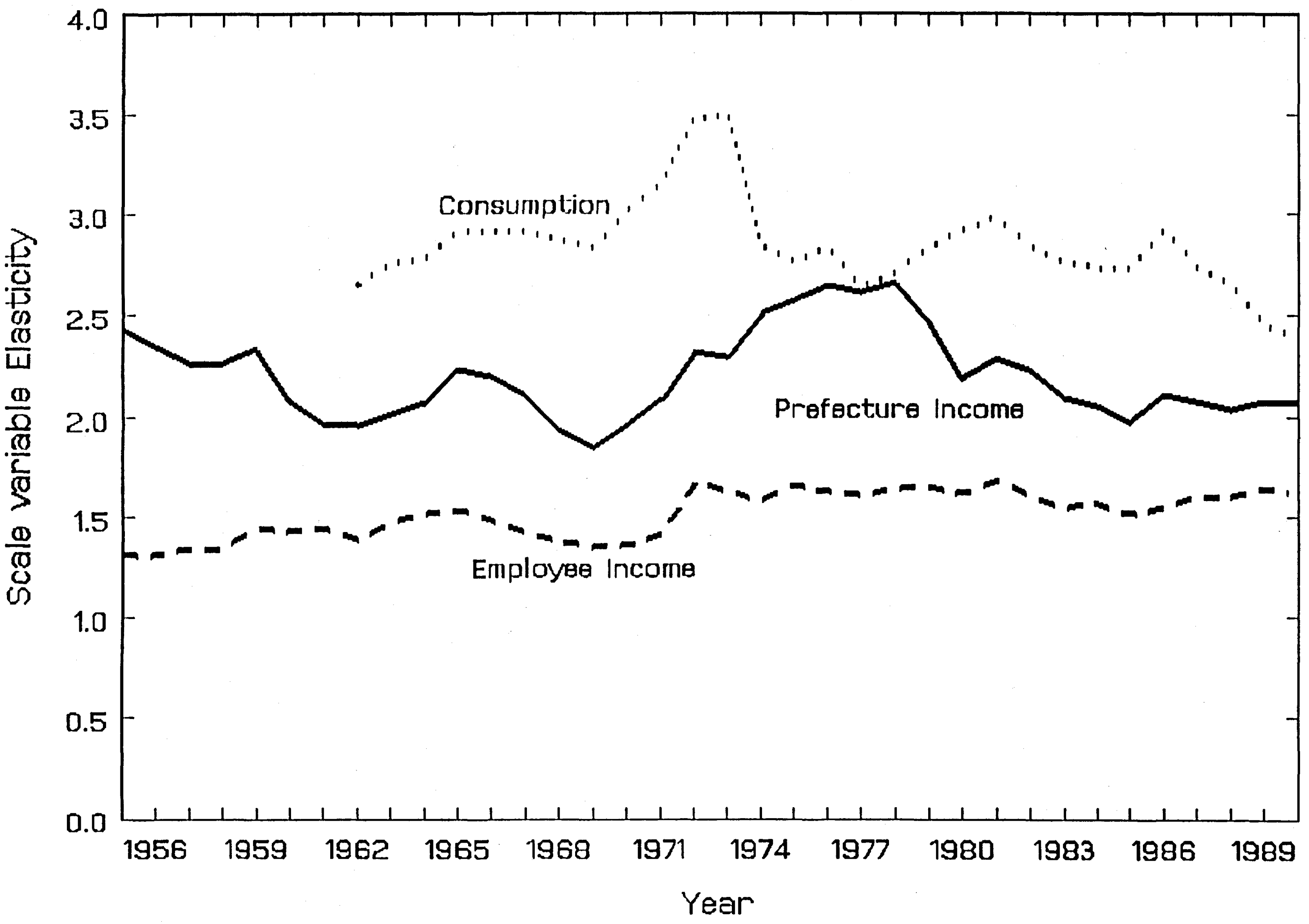

Fig.8. Choice of scale variables [use MF2, holding lnpd-lnpd4]

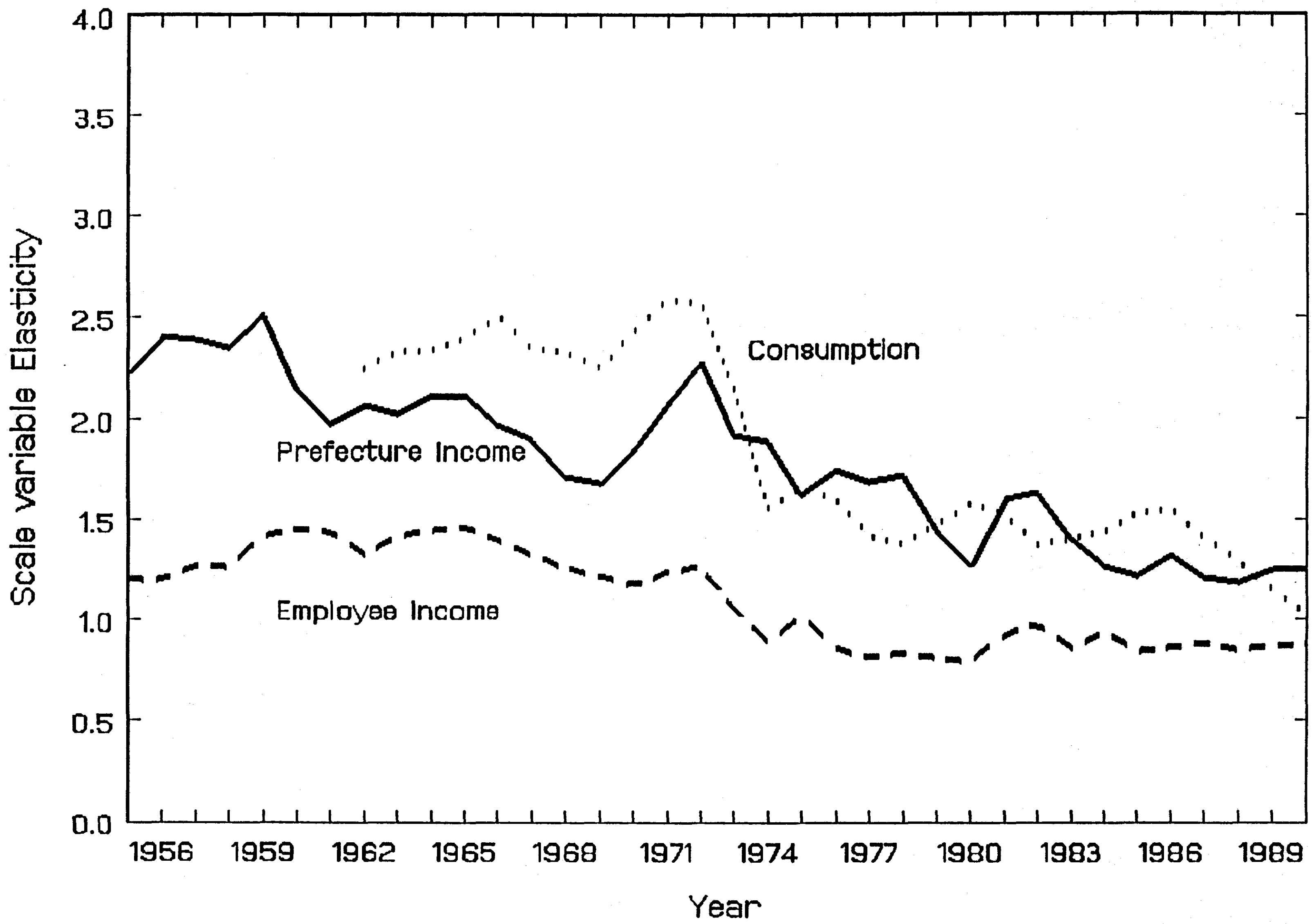

Fig.9. Choice of scale variables [MF2, holding SPI ln[PD]-ln[PD]^4]

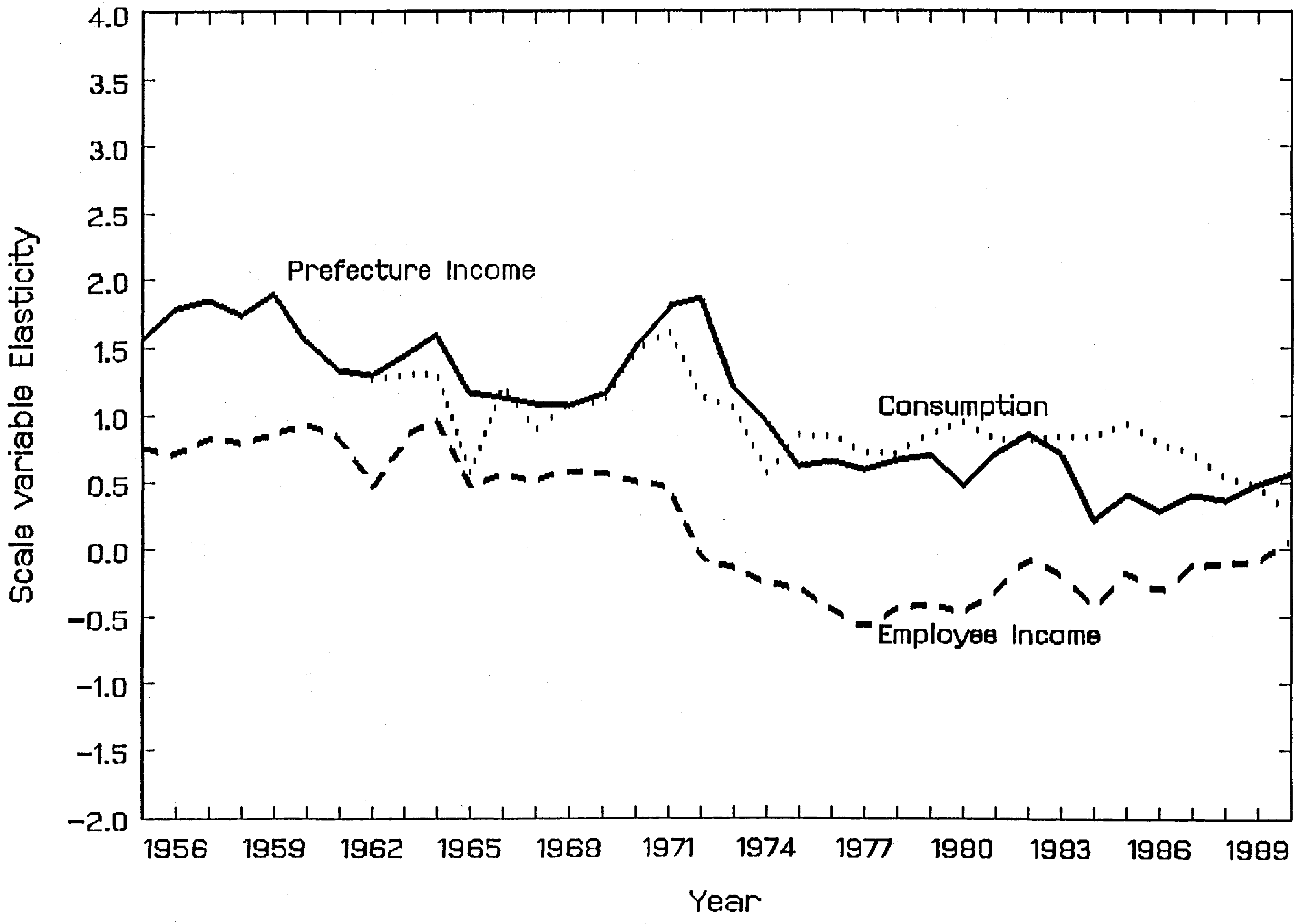

Fig.10. Prefecture Income Elasticity of MF2

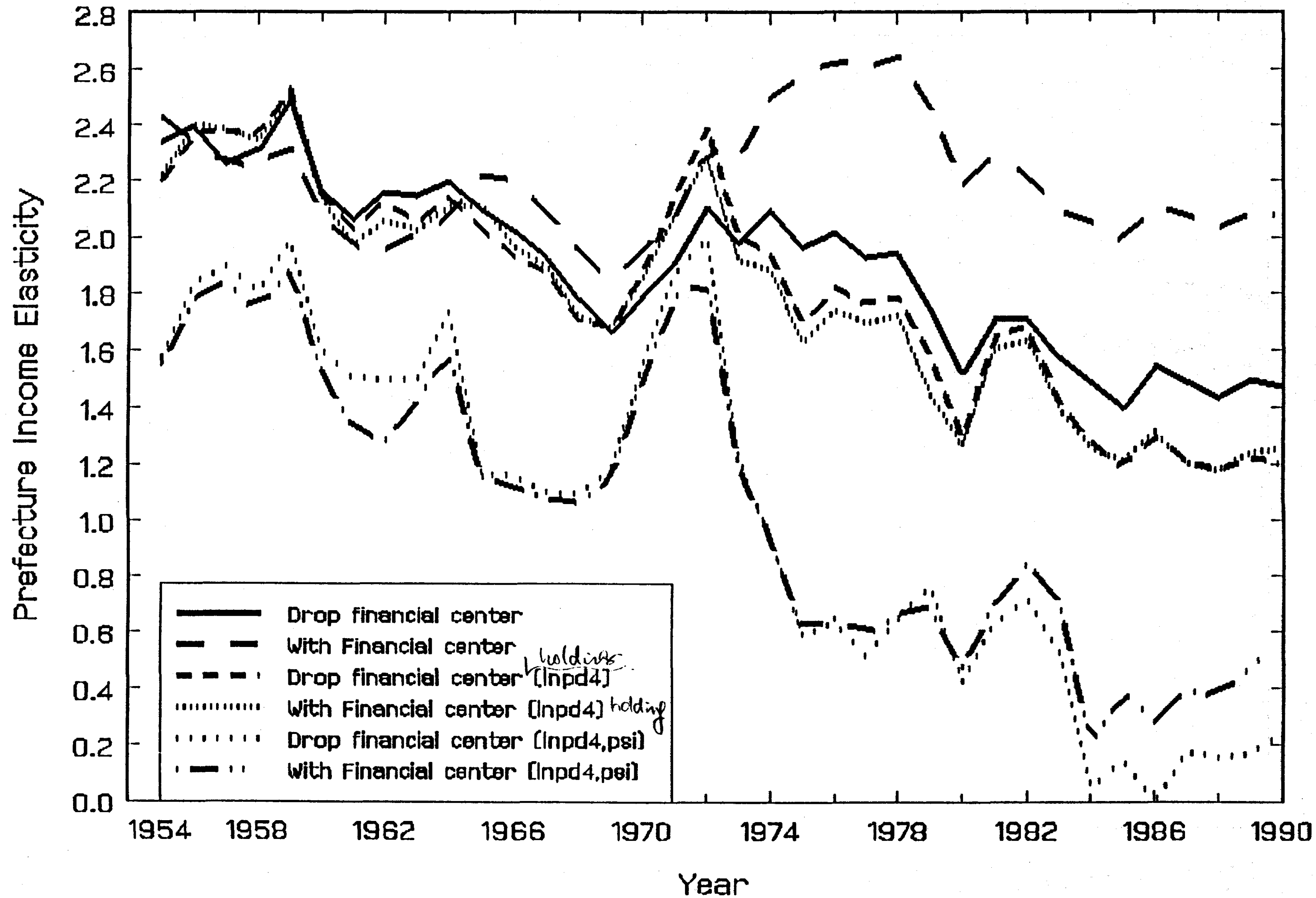

Fig.11. Prefecture Income Elasticity (Univariate)

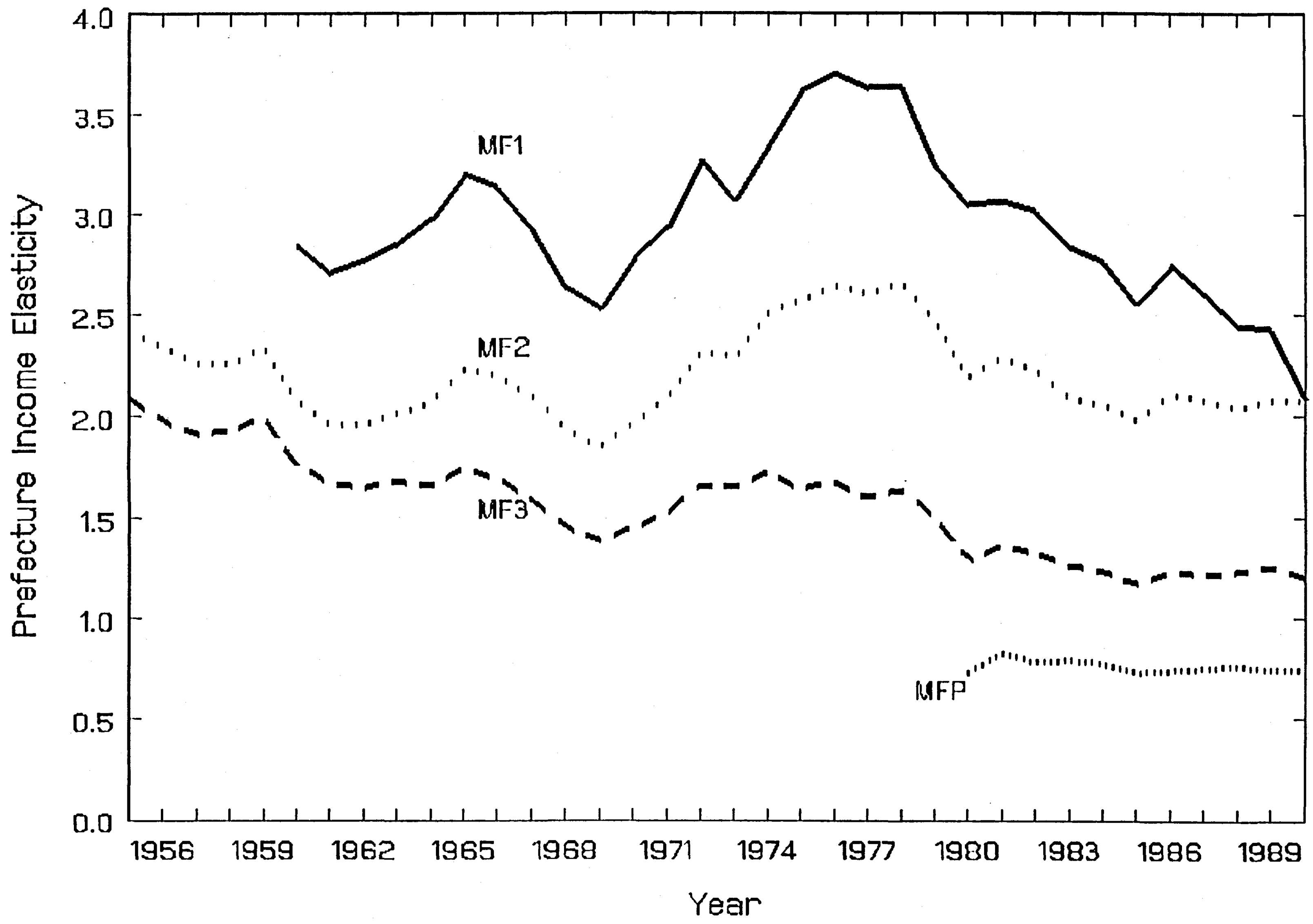

Fig.12. Prefecture Income Elasticity (With pd4)

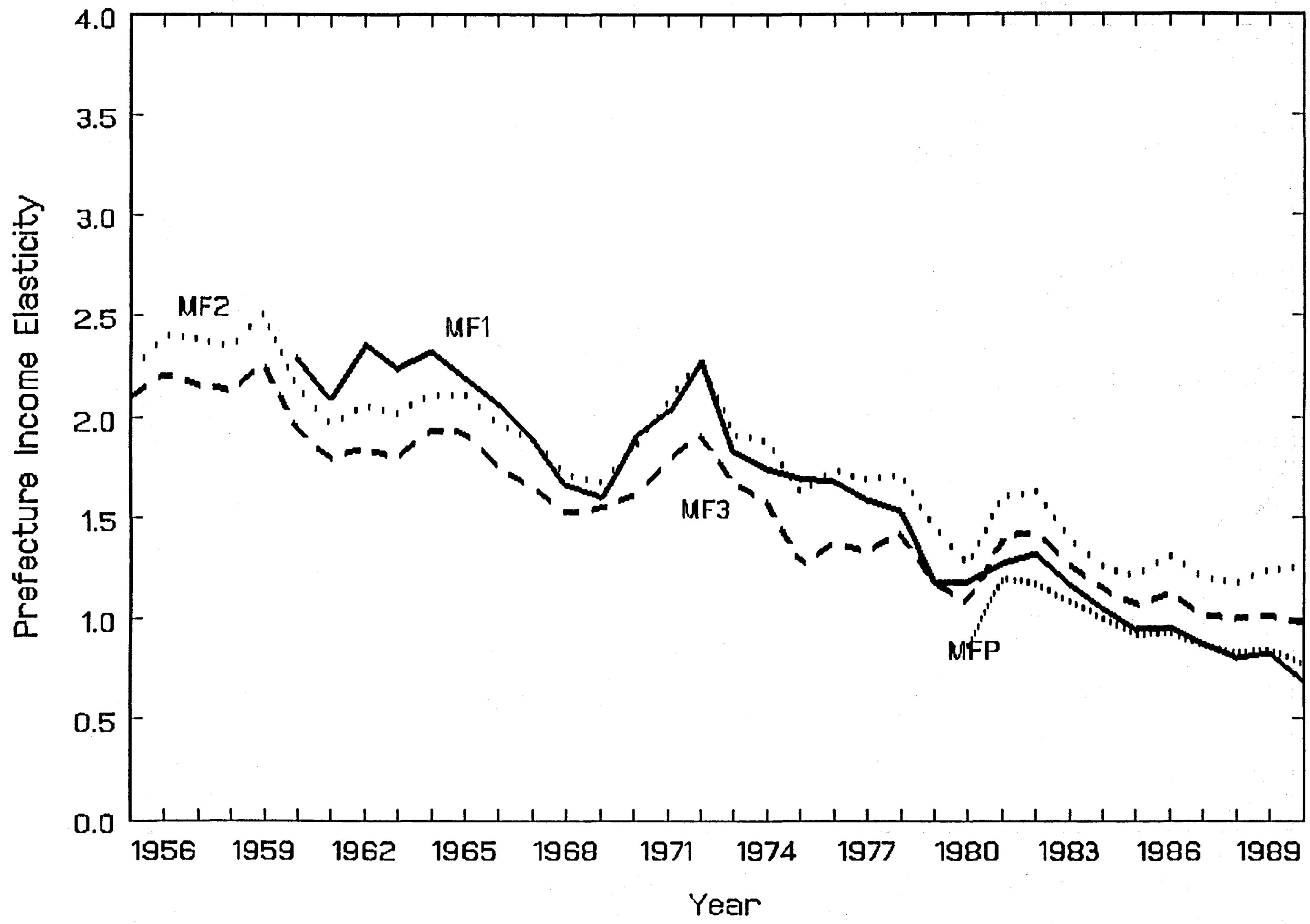

Fig.13. Prefecture Income Elasticity (With SPI,lnPD^4)

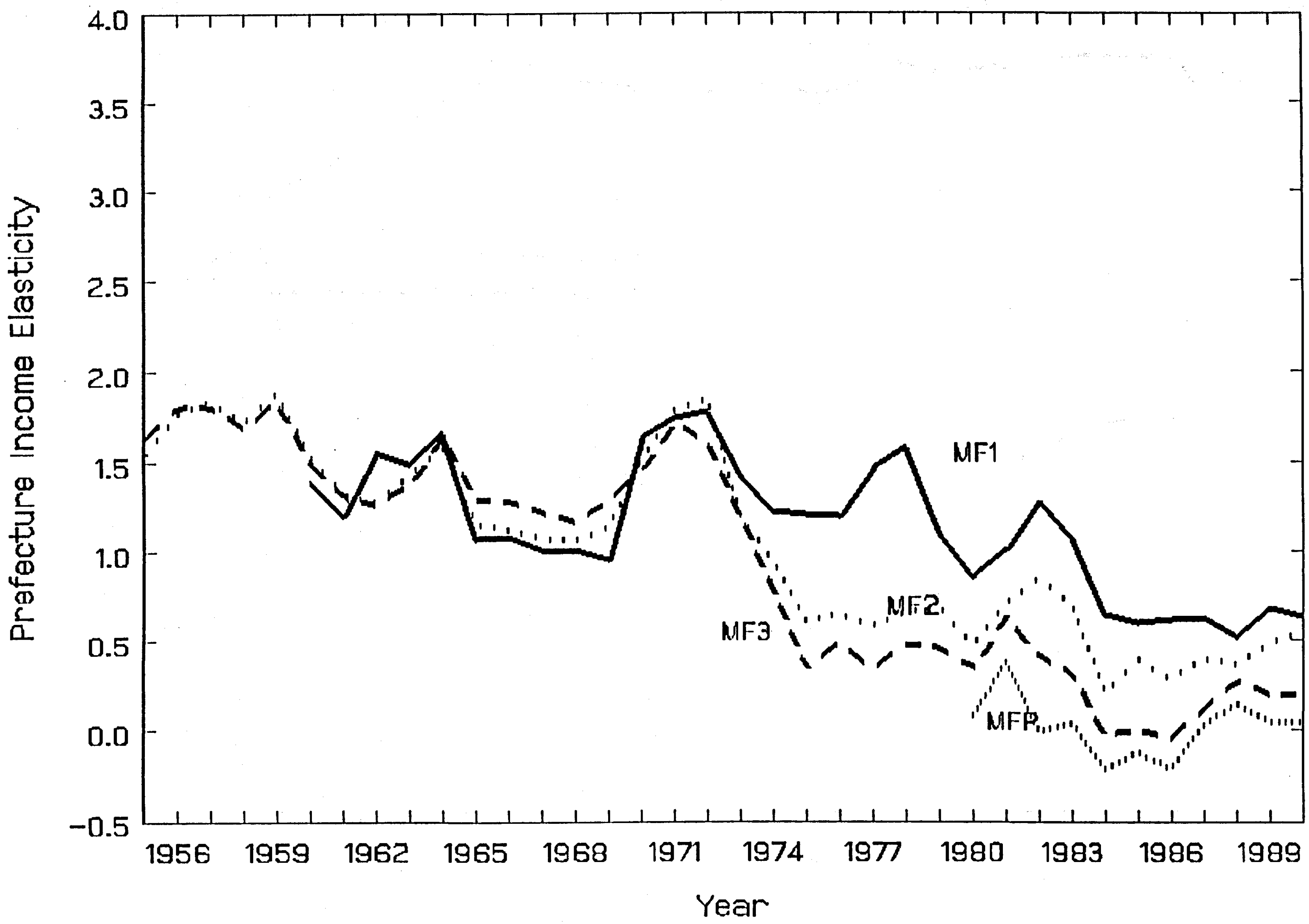

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Fig.14. Time effect of lnMF1 on Income

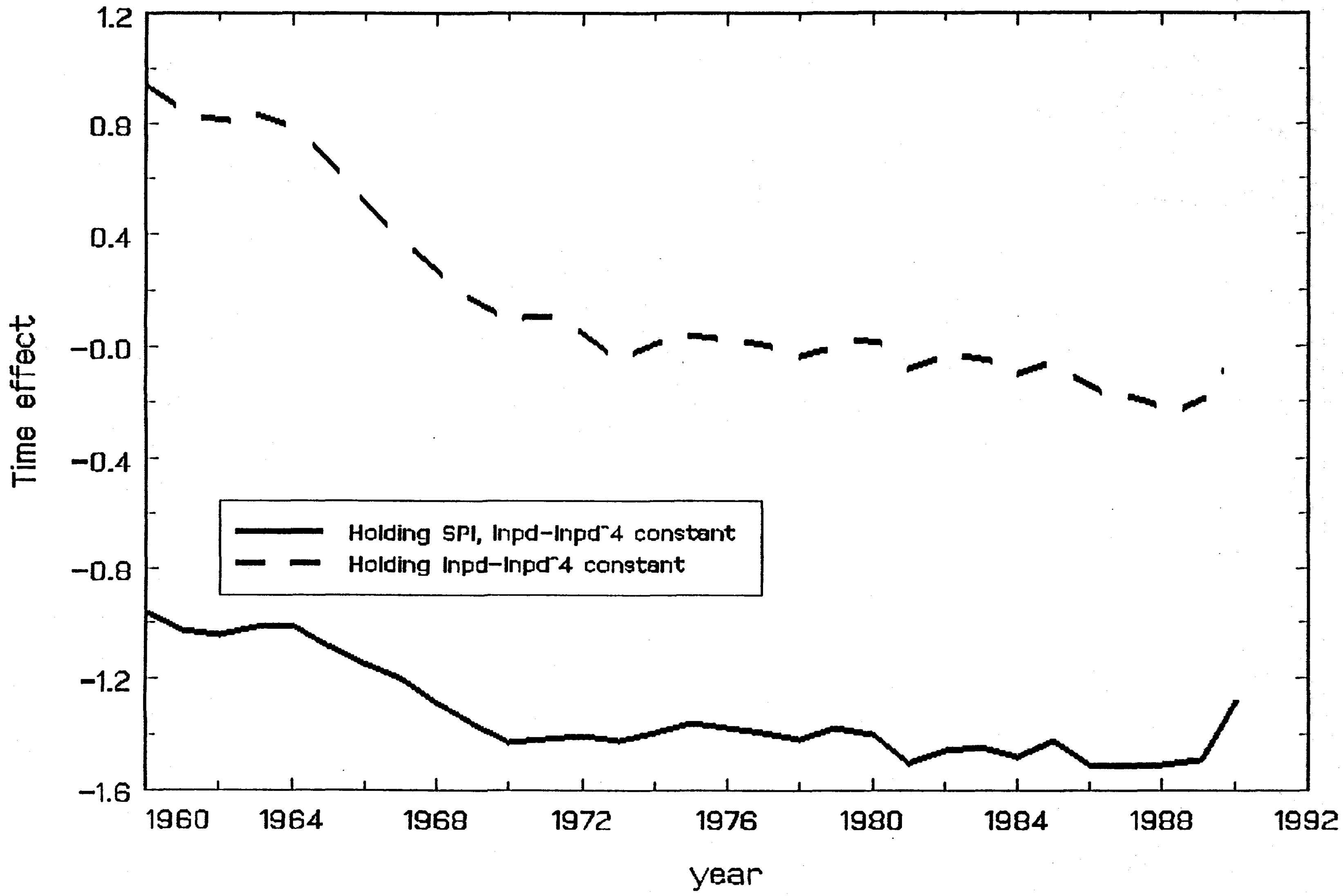

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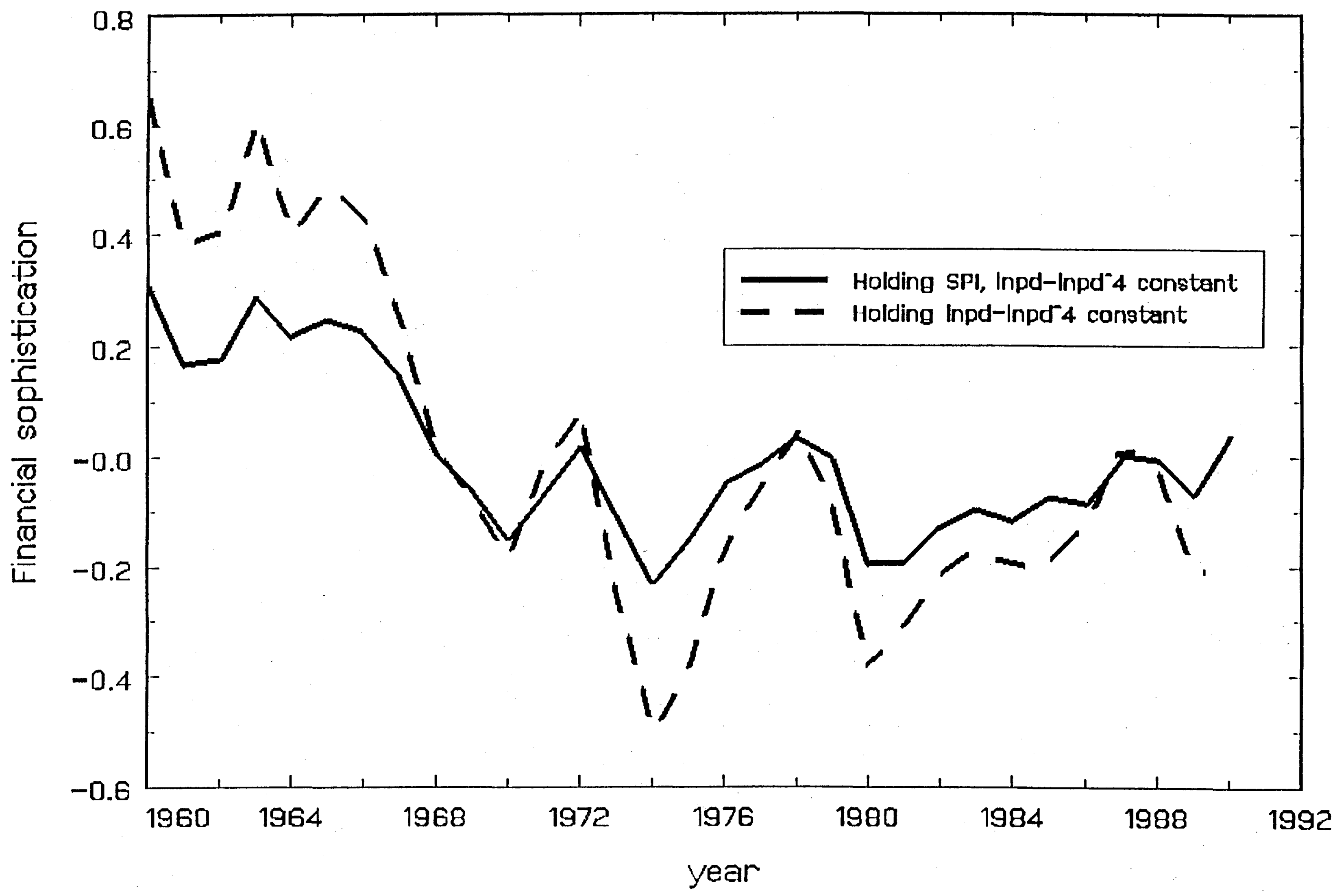
Fig.15. Time effect net of interest rate effect



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