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Abstract

We cross-sectionally estimate the income elasticity of money demand using Japanese prefectural deposit statistics and Japanese prefectural accounts statistics from fiscal 1955 to 2009 based on the structural model of Fujiki and Mulligan (1996a). In doing so, we update the results of Fujiki and Mulligan (1996a) using a similar data set from fiscal 1955 to 1990. Our analyses using the sample period of the 1980s confirm the finding of Fujiki and Mulligan (1996b) that the cross-sectional income elasticities of the sum of demand deposits and interest-bearing deposits, similar to the M2 statistics, range from 1.2 to 1.4. Our analysis using the sample period after 1990 shows that the cross-sectional income elasticities decrease gradually over time, and reach the value of 0.93 in 2003. Our analysis using data from 2004 to 2009 shows that the cross-sectional income elasticities take a value from 0.6 to 0.7. These results, taken at face value, suggest that households and firms save the monetary inputs for their production activities over time: the additional demand for money for an additional unit of production activity increased by more than one unit by the 1990s, while it increased by less than one unit after 2000.

Keywords: Demand for money; Income elasticity of money demand
JEL Classification: E6, F11, O47

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I. Introduction

The major benefit of financial innovation is that it makes possible an increase in trading with a reduced amount of collateral. To take a famous historical example, the use of fiat money allowed people to conduct more trading with less collateral than the use of convertible money. Fiat money derives its value only from the force of law and custom, as a kind of virtual collateral, while convertible money derives its value from metals, whose supply is limited. Another example of note is the use of demand deposits together with fiat money. The use of demand deposits as a medium of exchange, along with fiat money, allowed people to increase their trading using large-value amounts with safety.[1] The value of demand deposits at commercial banks derives in part from the credit of commercial banks, and thus conserves the use of collateral compared with a situation in which the same transactions are conducted based on bilateral transactions between private parties.

The extent of circulation of a particular type of deposit in an economy together with fiat money as a medium of exchange has differed from period to period and country to country, depending on the creditworthiness of the financial institutions and the development of new financial technology supporting new types of deposits.[2] Both central banks and academics seek to determine the adequate amount of deposits and fiat

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[1] A key to financial innovation lies in the creation of a medium of payments that makes possible an increase in trading with a reduced amount of collateral. Quinn and Roberts (2010) discuss a historical example from the Netherlands in the 17th century: the Bank of Amsterdam, which induced its customers to trade based on credit rather than coins, and succeeded in accumulating the latter thorough various types of financial innovation. Recent examples of financial innovation that substitutes fiat money include electronic money, debit cards, and a short message service-based money transfer system using a virtual account in one’s cellphone.

[2] Monetary economics considers the theoretical background when fiat money circulates as the medium of exchange. Such models include the search model (see Williamson and Wright [2011] for recent developments in monetary economics).

money in circulation in an economy. Central banks aim to grasp the amount because it could affect price stability or the stability of financial markets. Economists also seek to determine it, and they have estimated the demand for money as an empirical measure to judge the adequate amount of deposits and fiat money in circulation compared with the trading volume of an economy and the level of interest rates. They have found the estimation of the demand for money to be a challenging task, because financial innovation occurs continually, and thus it is difficult to answer on a real-time basis the question, "What is the adequate amount of deposits and fiat money in circulation given the creditworthiness of financial institutions and nations, and the level of economic development?"

Because of this challenge, central banks sometimes face a difficulty in explaining the intentions behind their conduct of monetary policy on a real-time basis. A noted example is the "missing money" episode in the United States in the 1970s. More specifically, if the demand for money was estimated using the U.S. time-series aggregate data including the data after 1973, the estimates of key parameters became unstable and forecast errors increased (Goldfeld [1976]). The loss of stability in the key parameters for demand for money means that the prerequisite for the conduct of monetary policy based on monetary targeting is lost. The Federal Open Market Committee (FOMC), which has announced an annual projection for the growth rate of monetary aggregates such as M1 since 1975, has found it difficult to make its annual projection using unstable key parameters of the demand for money.

Why does the U.S. demand for money become unstable after 1973? Researchers have concluded that the conventional methods for compiling monetary aggregates were the major factor behind this empirical finding. The conventional monetary aggregates add up the amount of bank deposits, assuming that these bank deposits are perfect substitutes. However, accelerating inflation in the 1970s induced financial institutions to innovate new financial products that allowed consumers to avoid the ceiling of interest rates on some of their bank deposits. These new financial products changed the substitutability between deposits, and thus it became more difficult to define the extent of deposits to be included in each monetary aggregate, on the grounds that the assumption of perfect substitutes sounded reasonable.[3]

The discovery of unstable demand for money due to financial innovation stimulated research on new methods for compiling monetary aggregates that took into account the imperfect substitutability among the financial products included within the same monetary aggregates.[4] The findings became a focus of research in not only macroeconomics but also the "economics of payment," which dealt with issues that overlapped with monetary economics and industrial organization.[5]

Macroeconomics pays less attention to the demand for money in theoretical,

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[3] Milton Friedman argued that currency plus all commercial bank deposits would have required a rate of growth of slightly more than 4%. The rate of increase, 4%, was chosen to correspond with the stable long-run level of the final product price. He also recommended a somewhat higher (lower) growth rate if a broader (narrower) definition of money obtained (Friedman [1960, p. 91]).

[4] See Serletis (2007, chapters 15 and 16), for a review of the microeconomic foundation of the definition of money and several new monetary aggregates such as Divisia monetary aggregates.

[5] Green (2004) notes, "Payment economics comprised the topics common to monetary economics and industrial organization." Kahn and Roberds (2009) survey the economics of payments and discuss some distinctions between monetary economics and industrial organization. The search model, which belongs to monetary economics, studies why fiat money circulates in an economy. However, models of economics of payments assume that fiat money circulates *a priori*. Consequently, research has looked at the institutional setup to see why both fiat money and substitutes for fiat money invented by a financial innovation circulate in an economy. Specifically, such research supposes a mismatch in timing of the trade or an inability to enforce a future trade for a trading partner. The assumptions justify the circulation of fiat money in an economy. Researchers have also studied the institutional setup to see why several substitutes for fiat money circulate in an economy under recurring financial innovation within the framework of the economics of information or mechanism design.

empirical, and policy studies, as we will discuss later in this chapter. Given continued financial innovation, however, we would argue that estimation of the demand for money through a number of empirical methods and examination of its stability remains an important research question.

Based on the structural model proposed by Fujiki and Mulligan (1996a), several research papers compared the income elasticities of money demand estimated from cross-sectional regional data or individual data with those estimated from the macroeconomic time series.[6] These studies aimed to grasp the secular changes in the income elasticity of money demand. Sharing the same motivation as these studies cited in the footnote above, this paper cross-sectionally estimates the income elasticity of money demand using Japanese prefectural deposit statistics and Japanese prefectural accounts statistics from fiscal 1955 to 2009 based on the structural model of Fujiki and Mulligan (1996a). In doing so, we update their results using a similar data set from fiscal 1955 to 1990.

Fujiki and Mulligan (1996a) propose a theoretical framework for studying the demand for money. According to one of their models, the national real money balance per capita, together with a log-linear approximation, depends on average household income, the nominal interest rate, and the ratio of the price of goods needed for transactions to the nominal interest rate, and the level of financial technology to employing financial transactions based on money.

Based on their structural model, Fujiki and Mulligan (1996b) estimated the following empirical money demand function:

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[6] For examples of estimations based on regional cross-sectional data, see Fujiki and Mulligan (1996a, b), Fujiki (1999, 2002), and Fujiki, Hsiao, and Shen (2002). For examples of estimations based on individual household data, see Fujiki and Shioji (2006) and Fujiki and Hsiao (2008).

$$\log\left(\frac{\text{Deposits per capita}_{it}}{\text{CPI}_{it}}\right) = a_t + b_t \log\left(\frac{\text{Prefectural income per capita}_{it}}{\text{CPI}_{it}}\right) + c_t Z_{it} + e_{it},$$

where a is a constant term, Z is a vector of independent variables such as the proxy variables for the difference in the level of financial technology across prefectures, e is an error term, subscript i shows the prefecture, and subscript t shows the time period. The estimates of income elasticity of money demand, b, correspond to the estimates of the structural parameter of the production function of household and firms in one of the theoretical models proposed by Fujiki and Mulligan (1996a).

Fujiki and Mulligan (1996b) used Japanese prefectural deposit statistics and Japanese prefectural accounts statistics from fiscal 1955 to 1990 and found that the estimates of income elasticity for money demand, b, took a value between 1.2 and 1.4. Their results were consistent with the long-run equilibrium income elasticity obtained from the error correction model using Japanese aggregate time-series data by Yoshida and Rasche (1990).

We extend the period of their estimation by adding the data from fiscal 1991 to 2009. The extension requires us to consider several additional issues regarding the background for the estimation and the data.

Regarding the background for the estimation, we must take into account two issues.

First, the Japanese economy has been characterized by low interest rates since the mid-1990s. Fujiki and Mulligan (1996b) argued that the cross-sectional estimates of the demand for money, holding the interest rate given, helped resolve the simultaneous bias of income and interest rates that might contaminate time-series estimates of income elasticity. In a period of low interest rates, deriving interest rate elasticity from time-series analysis becomes much more difficult because the interest rate data lack sufficient variation for estimation. The changes seem to enhance the merit of cross-sectional estimates, as argued by Fujiki and Watanabe (2004).[7] Second, Japan has experienced a rapid decrease in the growth rate of the population since the mid-1990s. Theoretically, the effects of population aging can increase or decrease the demand for deposits. For example, in regard to household savings, some households save more in preparation for their consumption after their retirement, while others reduce their savings to finance consumption after their retirement. It is not known in advance which of the two effects will dominate, and thus the overall effect should be examined by empirical study. Although the structural model of Fujiki and Mulligan (1996b) is static, we examine the effects of population aging using a proxy variable.

Regarding our data for estimation, we should note two changes in the definition of Japanese statistics for the sample period from 1991 to 2009 in our empirical study. First, money stock statistics were revised several times between 1991 and 2009. In particular, while the former M1 only covers demand deposits at M2+CD depository institutions, the revised M1 covers demand deposits at all depository institutions, including Japan Post Bank, agricultural cooperatives, Shinkumi banks, and so on.[8] Second, regarding the statistics on deposits, vault cash, and loans and bills discounted by prefecture (hereafter "prefectural deposit statistics"), after the end of fiscal 2003 statistics are unavailable for *shinkin* banks and *shoko chukin* banks compiled by the

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[7] The macroeconomic effects of paying interest on central bank reserve balances, such as the Bank of Japan's complementary deposit facility established in 2008, became an important issue during the recent financial crisis. Few studies of general equilibrium exist on this topic (a notable exception is Ireland [2012]), particularly on the effects of paying interest on central bank reserve balances on the demand for money by households and firms, and we do not deal with this issue in this paper.

[8] For details, see Bank of Japan (2008).

location of branches. Because of this change, we cannot compile the prefectural deposits that cover the financial institutions included in the former M2+CD statistics, on which Fujiki and Mulligan (1996b) focused. Hence, our prefectural deposit statistics show a few discontinuities, particularly in fiscal 2003. In comparing our results before and after 2003, these statistical discontinuities should be kept in mind.

Below we summarize the main empirical findings of this paper.

First, our analyses using the sample period of the 1980s confirm the finding of Fujiki and Mulligan (1996b) that the cross-sectional income elasticities of the sum of demand deposits and interest-bearing deposits, similar to the M2 statistics, range from 1.2 to 1.4. Our analysis using the sample period after 1990 shows that the cross-sectional income elasticities decrease gradually over time, and reach the value of 0.93 in 2003. Our analysis using data from 2004 to 2009 show that the cross-sectional income elasticities take a value from 0.6 to 0.7. These results, taken at face value, suggest that households and firms save the monetary inputs for their production activities over time: the additional demand for money for an additional unit of production activity increased by more than one unit in the 1990s, while it increased by less than one unit after 2000.

Second, holding other variables such as income constant, the addition of a proxy variable of population aging does not greatly change the size of income elasticity of the demand for money. Before moving on to the details of the analysis, we review the related literature for this study.

In this regard, first, looking at previous studies of the income elasticity of money demand using Japanese prefectural deposit statistics and Japanese prefectural accounts statistics, we can state that the closest approximation to our study is Kama (1988).

Kama (1988) regresses Japanese prefectural bank deposits (net of postal savings) from fiscal 1965 to 1985 on a constant term, the net prefectural product, the share of primary industry to prefectural income, the population density of each prefecture, a dummy variable that takes the value of one for Tokyo, and the number of branches of domestically licensed banks in each prefecture. He also estimates demand for money using a prefectural time series, and estimates the pooling regression. The empirical model used by Kama (1988) is very similar to Fujiki and Mulligan (1996b), but Kama (1988) does not provide a structural model to derive his empirical model.[9] Abiko (2006) runs a regression equation that employs the changes in prefectural bank deposits outstanding from a year earlier as a dependent variable, and prefectural income, land price, and wealth as independent variables. He also does not provide a structural model for his empirical model.

Second, we review the literature on demand for money in macroeconomics after 1990.[10] Unfortunately, we must point out the decreasing theoretical, empirical, and practical interest in the demand for money.

Regarding the theoretical perspective on the role of money, by the end of the 1990s New Keynesian models had become the standard model of monetary and macroeconomics, and these models assumed that a central bank conducted its interest rate policy based on the Taylor rule proposed by Taylor (1993), instead of monetary

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9 Kama (1988) used the number of branches of domestically licensed banks in each prefecture as one of the control variables. One may safely assume that the number of branches was under the control of the Ministry of Finance at that time and thus an exogenous variable. Indeed, Fujiki (1999) also used the number of the branches of domestically licensed banks in each prefecture as one of the control variables. In this paper, we do not do this, because it is possible that the secular increase in the number of ATMs at convenience stores and the prevalence of online banking has reduced the importance of the network of branches as a determinant of the size of bank savings.

10 For a recent survey on monetarism and inflation, see McCallum and Nelson (2011).

targeting.[11] Even the few economists who still emphasize the role of money acknowledge the limited theoretical and quantitative implication of money in New Keynesian models (McCallum [2012]). After the Federal Reserve began paying interest on central bank reserve balances in 2008, some economists pointed out that in such a framework one should not mechanically apply the credit multiplier approach between the monetary base and monetary aggregates.[12] Some economists have attempted to introduce money and the banking sector into macroeconomic models given the experience of the global financial crises, but researchers have not reached a consensus.[13]

Regarding the empirical perspective on the role of money, the loss of stability in the key parameters for the demand for money, as observed in the United States in the early 1970s, perhaps reflecting the financial innovation in those days, led to the loss of an empirical prerequisite for monetary targeting.[14]

In terms of a practical perspective on the role of money, major central banks moved toward the framework of flexible inflation targeting, and regarded the most powerful policy tool as the future path of the policy rates.[15] In this transition, many central banks deemphasized the analysis of the demand for money or monetary aggregates. For example, the Federal Reserve stopped compiling the M3 statistics on March 23, 2006.

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[11] See Goodfriend (2007) regarding the transition of the core macroeconomic model; a typical textbook on the subject is Galí (2008).

[12] See Keister, Martin, and McAndrews (2008) and Ireland (2012).

[13] See Goodfriend and McCallum (2007).

[14] See Goldfeld and Sichel (1990) for a comprehensive review of the literature on demand for money prior to 1990. For an explanation of the changes in the velocity of M1 and financial innovation (for example, the introduction of the Sweep account), see McCallum and Nelson (2011, chapter 4).

[15] See Woodford (2003) for such a view.

Third, we review the study on Japanese demand for money after the 1990s. As summarized by Sekine (1998), the stability of demand for M2+CDs in Japan was an open question during the 1990s.[16] In the decade after 2000, motivated by the introduction of the zero interest rate policy in 1999 and the quantitative easing policy in 2001, some economists following the monetarist tradition made policy proposals based on the quantity theory of money.[17] In the era of low interest rates, estimating interest rate elasticity from time-series data is much more difficult because the interest rate data lack sufficient variation for estimation. Some economists have nevertheless sought to test whether the Japanese economy has fallen into a liquidity trap, in the sense that the interest rate elasticity of demand for narrow money has become very elastic in an era of low interest rates.[18]

The rest of the paper is organized as follows. Section II discusses the theoretical model for the demand for money, Section III explains the data used in our analysis, and Section IV reports the results of estimation for the demand for money using time-series data and cross-sectional data, and the benchmark results of cross-sectional data. Section V checks the robustness of our benchmark results against the measurement error of the data arising from the discrepancy between the prefectural deposit statistics and the prefectural accounts statistics. Section VI checks the robustness of our benchmark results against the replacement of independent variables from gross prefectural expenditure (GPE) to prefectural private consumption (PPC). Section VII checks the robustness of our benchmark results against the replacement of dependent

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[16] See Yoshida (1990) for a literature review of empirical studies on the demand for money prior to the 1990s.

[17] See Hetzel (2004) .

[18] See Miyao (2002, 2005), Nakashima and Saito (2012), and Fujiki and Watanabe (2004).

variables from the deposits included in M2 to the deposits included in M1 or M3. Section VIII concludes with a discussion of the policy implications.

II. Theoretical Approaches to the Demand for Money

Serletis (2007) classifies the theoretical approaches to the demand for money into three categories: the quantity theory of money, transaction theories, and portfolio theories.[19]

For the quantity theory of money, some models assume that agents hold money as a medium of exchange and thus the size of transaction determines the demand for money. Other models assume that agents hold money as an asset to store value, and thus the level of permanent income determines the demand for money (Friedman [1956]).

Transaction theories emphasize money's role as a medium of exchange in the economy. Among them, Baumol (1952) and Tobin (1956) apply the inventory model to the cost (forgone income) and benefit (convenience) of holding money, and they show that in some settings the interest rate elasticity and income elasticity of the demand for money become –0.5 and 0.5, respectively. McCallum and Goodfriend (1988) propose a model in which trade with money, unlike the trade through barter, produces a large savings called "shopping time," and they derive the household real balance as a function of household consumption and the nominal interest rate in equilibrium. Lucas (1988) also derives the equilibrium relationship in which the household real balance is a function of household consumption and the nominal interest in a model with a cash-in-advance constraint proposed by Clower (1967).

Portfolio theories of money emphasize the role of money as a store of value. For example, the mean-variance model of Tobin (1958) derives the proportion of holding

[19] See Goldfeld and Sichel (1990) and Serletis (2007) for details.

risky assets and that of safe assets (money) among total assets. The overlapping generations model also shows the conditions under which fiat money is held by the agents to store value.[20]

Below we explain our theoretical model that leads to our empirical model of log-linear money demand proposed by Fujiki and Mulligan (1996b), which allows us to estimate the structural parameter of the theoretical model as the income elasticity of money demand from our prefectural statistics.

Fujiki and Mulligan (1996b) suppose that agent *i* produces final output *y* using input x_1 and transaction service *T* as shown in equation (1).

$$y_{it} = f(x_{1,it}, T_{it}, \lambda_f) = [(1-\lambda_f)x_{1,it}^{(\gamma-\beta)/\gamma} + \lambda_f(\frac{\gamma-\beta}{\gamma-1})T_{it}^{(\gamma-1)/\gamma}]^{\gamma/(\gamma-\beta)}, \qquad \textbf{(1)}$$
$$\lambda_f \in (0,1), \beta > 0, \gamma \in (0, \min(1,\beta)).$$

where λ_f is a productivity parameter invariant to the agent and time, subscript *i* stands for the economic agent, and subscript *t* shows the time period. If the economic agent *i* is a firm, equation (1) shows that the firm produces goods *y* using raw material x_1 and transaction service *T* obtained from financial institutions and *y* corresponds to observables such as firm sales. If the economic agent *i* is a household, variable *y* corresponds to unobservable household production goods proposed by Becker (1965) and Lancaster (1966).

Transaction service *T* is produced by the real money balance *m* and inputs x_3 (for example, automatic teller machine or the leisure hours sacrificed to go to banks to withdraw money), according to equation (2).

[20] See details in Blanchard and Fischer (1989, chapter 4) or Champ and Freeman (1994).

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

Here, *A* stands for a parameter for the productivity.

Suppose that a household minimizes the cost (equation (3)) subject to equations (1) and (2):

$$r_{it} = q_{1,t}x_{1,it} + q_{3,t}x_{3,it} + R_t m_{it}. \quad \textbf{(3)}$$

By solving the problem, the household obtains its cost function Ω. Partially differentiating the cost function Ω by the rental cost of real money balance, *R*, becomes the derived demand for the real money balance that depends on output *y*, rental cost *R*, and input price *q*.

$$\begin{aligned} \log m_{it} &= \log L(y_{it}, R_t, q_{it}, A_{it}) \quad \textbf{(4)} \\ &\approx \beta \log y_{it} - \gamma \log R_t + \pi_\phi(\psi_\phi - \gamma)\log\frac{q_{3,it}}{R_t} \\ &+ \gamma \log q_{1,it} - (1-\gamma)\log A_{it} + constant. \end{aligned}$$

If the economic agent *i* is a household, it is hard to obtain the proxy variable of *y*. Therefore, it is useful to derive the demand for money that does not depend on *y*. To this end, we first invert the cost function Ω to obtain $\mathrm{y_{it} = \Omega^{-1}(r_{it}, R_t, q_t, A_{it}, \lambda_f)}$. Then we plug this result into equation (4) and obtain the Marshallian demand for money, which does not depend on *y* (Equation (5).

$$
\begin{aligned}
\log m_{it} &= \log M(r_{it}, R_t, q_{it}, A_{it}) \qquad \textbf{(5)} \\
&\approx \beta \log r_{it} - \gamma \log R_t + \pi_\phi (\psi_\phi - \gamma) \log \frac{q_{3,it}}{R_t} \\
&\quad + (\gamma - \beta) \log q_{1,it} - (1-\gamma) \log A_{it} + constant.
\end{aligned}
$$

Finally, we obtain the derived demand for the real balance with respect to x_1 given input price q_1, rental cost R, and output y by partially differentiating the cost function Ω by q_1, as shown in equation (6).

$$
\begin{aligned}
\log m_{it} &= \log g_1(x_{1,it}, R_t, q_{it}, A_{it}) \qquad \textbf{(6)} \\
&= \beta \log x_{1,it} - \gamma \log R_t + \pi_\phi (\psi_\phi - \gamma) \log \frac{q_{3,it}}{R_t} \\
&\quad + \gamma \log q_{1,it} - (1-\gamma) \log A_{it} + \text{constant}.
\end{aligned}
$$

Suppose that x_1 is a consumption good. Then, equation (6) corresponds to the models in which demand for money depends on real consumption, such as McCallum and Goodfriend (1988), Lucas (1988), and Clower (1967).

Equations (4) through (6) show that the production, income, and consumption elasticity of money demand take the common value of β, and the interest rate elasticity takes the common value of γ, although the elasticity with respect to q_3 varies from equation to equation.

If we have micro data on firms and households, we can estimate equation (4) for firms and equations (5) or (6) for households. However, in many cases we can only use aggregate data such as industry or regional aggregates. In this context, it would be helpful if the parameter for the demand for money for firms and individuals, equations (4) through (6), could be estimated from some aggregate data. Using the property that for households *r* is equal to income, which is denoted as *I*. Suppose that the household income I_{it}, firm income y_{it}, the productivity of transaction service, and input prices follow the log-normal distribution as in the equations below.

$$\begin{aligned} &\log(I_{it}) \sim N[\mu_{i,t}(h), \sigma_{It}^2(h)] \\ &\log(q_{j,it}) \sim N[\mu_{j,t}(h), \sigma_{jt}^2(h)],\ j = 1,3. \\ &\log(A_{it}) \sim N[\mu_{A,t}(h), \sigma_{At}^2(h)] \end{aligned} \qquad \textbf{(7)}$$

$$\begin{aligned} &\log(y_{it}) \sim N[\mu_{y,t}(f), \sigma_{yt}^2(f)] \\ &\log(q_{j,it}) \sim N[\mu_{j,t}(f), \sigma_{jt}^2(f)],\ j = 1,3. \\ &\log(A_{it}) \sim N[\mu_{A,t}(f), \sigma_{At}^2(f)] \end{aligned} \qquad \textbf{(8)}$$

Under the log-normal distribution assumption above, we can derive the following aggregate demand for money as below.

First, equation (9) shows the aggregate demand for money by household, where $N_t(h)$ is the number of households, $I_t(h)$ is the average household income, and $m_t(h)$ is the average household real balance.

$$\begin{aligned} \log m_t(h) = {} & \beta \log I_t(h) - \gamma \log R_t \\ & + \pi_\phi(\psi_\phi - \gamma)\log\frac{q_{3,t}(h)}{R_t} + (\gamma - \beta)\log q_{1,t}(h) - (1-\gamma)\log A_t(h) \\ & + \frac{1}{2}\beta(\beta - 1)\sigma_{It}^2(h) + \frac{1}{2}\pi_\phi(\psi_\phi - \gamma)[\pi_\phi(\psi_\phi - \gamma) - 1]\sigma_{3t}^2(h) \\ & + \frac{1}{2}(1-\gamma)(2-\gamma)\sigma_{At}^2(h) + \frac{1}{2}(\gamma - \beta)(\gamma - \beta - 1)\sigma_{1t}^2(h) \\ & + \text{covariances} + \text{constant}. \end{aligned} \qquad \textbf{(9)}$$

Second, equation (10) shows the aggregate demand for money by firms, where $N_t(f)$ is the number of firms, $y_t(f)$ is the average firm sales, and $m_t(f)$ is the average firm real balance.

$$
\begin{aligned}
\log m_t(f) &= \beta \log y_t(f) - \gamma \log R_t \\
&+ \pi_\phi(\psi_\phi - \gamma)\log \frac{q_{3,t}(f)}{R_t} + \gamma \log q_{1,t}(f) - (1-\gamma)\log A_t(f) \\
&+ \frac{1}{2}\beta(\beta-1)\sigma_{yt}^2(f) + \frac{1}{2}\pi_\phi(\psi_\phi-\gamma)[\pi_\phi(\psi_\phi-\gamma)-1]\sigma_{3t}^2(f) \\
&+ \frac{1}{2}(1-\gamma)(2-\gamma)\sigma_{At}^2(f) + \frac{1}{2}\gamma(\gamma-1)\sigma_{1t}^2(f) \\
&+ \text{covariances} + \text{constant.}
\end{aligned} \quad \textbf{(10)}
$$

Finally, equation (11) shows the per capita real balance, which is a log-linear approximation of the sum of the demand for money by firms and those of households, log $[m_t(\mathrm{f})+m_t(\mathrm{h})]$. Note that N_t shows population, $\eta_t(\mathrm{f})=N_t(\mathrm{f})/N_t$, $\eta_t(\mathrm{h})=N_t(\mathrm{h})/N_\mathrm{t}$, and $v_t = [N_t(\mathrm{f})/N_t(\mathrm{h})]/[y_t(\mathrm{f})/I_t(\mathrm{h})]$.

Fujiki and Mulligan (1996b) offer the following interpretation on equation (11).

$$
\begin{aligned}
\log\left(\frac{M_t}{P_t N_t}\right) &= \beta \log y_t(h) - \gamma \log R_t \\
&+ \pi_\phi(\psi_\phi-\gamma)\left[\omega \log \frac{q_{3,t}(f)}{R} + (1-\omega)\log \frac{q_{3,t}(h)}{R_t}\right] \\
&+ \omega\gamma \log q_{1,t}(f) + (1\text{-}\omega)(\gamma-\beta)\log q_{1,t}(h) \\
&- (1-\gamma)[\omega \log A_t(f) + (1\text{-}\omega)\log A_t(h)] \\
&+ [\omega \log \eta_r(f) + (1\text{-}\omega)\log \eta_t(h)] + \beta\omega\left[\log v_t + \log \frac{\eta_t(h)}{\eta_t(f)}\right] \\
&+ \frac{1}{2}\beta(\beta-1)[\omega\sigma_{yt}^2(f) + (1-\omega)\sigma_{It}^2(h)] \\
&+ \text{other covariances.}
\end{aligned} \quad \textbf{(11)}
$$

The first line of the right-hand side of equation (11) shows the effects of income and the nominal interest rate on the demand for money. Typical empirical studies on the demand for money use only these two variables as independent variables.

The second and third line of the right-hand side show the weighted-average effects of relative prices for the demand for money by household and firms, respectively.

The fourth line of the right-hand side shows the weighted average of the level of transaction technology by household and firms. Depending on whether the value of parameter γ exceeds one or not, the rise in the level of the transaction technology reduces or increases the demand for money.

The fifth line of the right-hand side shows that the per capita real money balance depends on the number of firms and households and the share of the firm income relative to household income. The last term shows that as more firms become involved in the process of production, the demand for money increases. The property comes from our assumption that both firms and household demand money.

The last line of the right-hand side shows that if there is a scale economy in a sense that $\beta < 1$, the demand for money decreases as the standard deviation of income increases.

Fujiki and Mulligan (1996b) do not consider the effects of population aging. However, the effects of population aging could affect the demand for money through various channels. For example, the substitutability of real balance m and goods x_3 could differ for old agents and young agents (for example, young people make more use of online transactions). The level of income or the income distribution might change as population aging proceeds. In this paper, instead of explicitly modeling the population aging, we introduce a proxy variable for population aging and empirically examine the bias arising from omitting such a variable.

Next, let us explain why we seek to estimate equation (11) cross-sectionally. Fujiki and Mulligan (1996b) point out the following reasons.

First, cross-sectional data, such as prefectural deposit statistics and prefectural accounts statistics, help us to identify the income elasticity of the demand for money, because the nominal interest rate, prices for goods, and the level of transaction technology are given at a particular time, consistent with the definition of income elasticity as "changes in the demand for money with additional income, given the level of interest rate." Moreover, the estimates of the income elasticity, β, correspond to the structural parameter of the production function defined in equation (1). Therefore, the estimate of income elasticity of the money demand through equation (11) is also an estimate of structural parameter β.

Second, we can easily examine the structural changes in the demand for money by comparing the annual cross-sectional estimates for each sample period.

Third, the problem of changes can be avoided in the definition of money. At least, cross-sectionally, all the statistics are compiled consistently.

Of course, the cross-sectional estimation is not a panacea for all difficulties arising from the estimation for the demand for money, for three reasons.

First, cross-sectional estimation requires additional control variables not required by the time-series analysis, for example, the proxy to control for the prefectural heterogeneity of the demand for money that could originate from the degrees of population aging or degrees of urbanization.

Second, some of the cross-sectional statistics, especially the prefectural accounts statistics, become available with a substantial delay compared with the time-series data.[21]

Third, the cross-sectional estimation does not allow us to estimate the interest rate elasticity of money demand directly, because the effects of the interest rate on money demand are absorbed in the constant term together with the effects of relative prices.

However, if we can use panel data or repeated cross-sectional data, we can test the extent to which extent our assumptions for the aggregation make sense. For example, Fujiki and Hsiao (2008) used repeated cross-sectional household survey data and estimate both equations (5) and (9), and compare the income elasticities obtained in each equation.[22] To the best of our knowledge, no empirical studies compare the estimates of equations (4) and (10) using the micro data for firms.[23]

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[21] Fujiki (1999) provided a partial solution to the publication lag for the prefectural accounts statistics. He compiled monthly series of household consumption and household income for 10 regions from monthly household survey data from 1985 to 1995, and regressed the data on monthly personal deposit statistics for domestically licensed banks following the model of Fujiki and Mulligan (1996b). He found that the income elasticities of household demand for money from 1990 to 1995 are in the range of 1.28 to 1.35, which is consistent with the results obtained from the annual data.

[22] Fujiki and Hsiao (2008) first estimated equation (5) cross-sectionally using the repeated cross-sectional household survey data from 1991 to 2002. Independent variables were household deposits close to the definition of M1, M2, and M3, income data in the survey were used for explanatory variable I, and average hourly wages obtained from the basic wage survey were used for the proxy variable of explanatory variable q_3. In addition, they controlled for the dummy variables of house ownership, and the size of the household. Next, they aggregated the individual household data from 1991 to 2002 and estimated equation (9) together with the data on interest rates and the standard deviation of income and wages. They found that the income elasticity for deposits close to M3 obtained from equation (5) took a value from 0.53 to 0.85, while the estimates from equation (9) took values 0.66 or 0.86 depending on the choice of interest rate series. The estimates obtained from the two equations were roughly comparable. Other estimates for the demand for money by household from the household micro data include Suzuki (2010) and Takezawa and Matsuura (1998, 1999).

[23] Hsiao, Shen, and Fujiki (2005) compare the estimates of equation (11) on the different degrees of aggregations. They compare the estimates from the prefectural data and the estimates from the simulated aggregate data from the prefectural data. In the United States, there are many empirical studies on the demand for money by firms such as Meltzer (1963a). Mulligan (1997) estimates the model explained in this paper using the U.S. firm data.

III. Data

In this section, we explain the data used for the regression: the prefectural deposit statistics, the prefectural accounts statistics, and other data. All data exclude Okinawa Prefecture.

A. Prefectural Deposit Statistics

This paper compiles a few series of per capita prefectural deposits deflated by the GPE deflator as the measure of the prefectural real money balance. We use per capita data to be consistent with our theoretical model, equation (11).

For the prefectural real money balance, we focus on the counterpart of M2 statistics in the Japanese money stock statistics (formerly M2+CDs in the Japanese money supply statistics) because the Bank of Japan has been presenting M2 in its *Monthly Report of Recent Economic and Financial Developments.* Other prefectural real money balance series will be used for the sake of a robustness check.

We compute three types of prefectural money stock, MF1, MF2, and MF3, which are the counterpart of M1 minus currency, M2 minus currency, and M3 minus currency.

Note that while the former M1 only covers demand deposits at M2+CD depository institutions, currently M1 covers demand deposits at all depository institutions, including Japan Post Bank, agricultural cooperatives, Shinkumi banks, and so forth. Note also that after the end of fiscal 2003, the prefectural deposit statistics for *shinkin* banks and *shoko chukin* banks compiled by the location of branches are unavailable. Because of these changes, we cannot compile prefectural deposits that cover the financial institutions included in old M2+CD statistics, on which Fujiki and Mulligan

(1996b) focused. Hence, our prefectural deposit statistics have a few discontinuities, especially in fiscal 2003.

MF1 is defined as demand deposits at the end of the fiscal year. MF1 covers demand deposits at domestically licensed banks from 1959 to 2002, and also covers demand deposits at Japan Post Bank from 2003 to 2009.

Compared with M1, MF1 after 2003 does not include demand deposits at foreign banks in Japan, the Shinkin Central Bank, *shinkin* banks, the Norinchukin Bank, the Shoko Chukin Bank, the Shinkumi Federation Bank, Shinkumi banks, the Rokinren Bank, labor banks, the Prefectural Credit Federation of Agricultural Cooperatives, agricultural cooperatives, the Prefectural Credit Federation of Fishery Cooperatives, and fishery cooperatives. Note that MF1 does not include currency, while it includes deposits held by financial institutions not included in M1.

MF2 is defined as the sum of demand deposits, time deposits, and foreign currency deposits at the fiscal year-end. MF2 covers deposits at domestically licensed banks (except for Japan Post Bank), mutual banks, *shinkin* banks, the Shoko Chukin Bank from 1955 to 1987, and covers domestically licensed banks (except for Japan Post Bank), *shinkin* banks, the Shoko Chukin Bank from 1988 to 2003, and domestically licensed banks (except for Japan Post Bank) after 2004.

Compared with M2, MF2 after 2004 does not cover demand deposits and time deposits at foreign banks in Japan, the Shinkin Central Bank, *shinkin* banks, or the Norinchukin Bank. Note that MF2 does not include currency, while it includes deposits held by financial institutions other than domestically licensed banks not included in M2.

MF3 is defined as the sum of demand deposits, time deposits, and foreign currency deposits at the fiscal year-end. MF3 includes deposits at domestically licensed banks (except for Japan Post Bank), mutual banks, *shinkin* banks, the Shoko Chukin Bank, the Shinkumi Federation Bank, Shinkumi banks, the Rokinren Bank, labor banks, the Prefectural Credit Federation of Agricultural Cooperatives, agricultural cooperatives, the Prefectural Credit Federation of Fishery Cooperatives, and fishery cooperatives from 1955 to 1987. MF3 includes deposits at domestically licensed banks (except for Japan Post Bank), *shinkin* banks, the Shoko Chukin Bank, the Shinkumi Federation Bank, Shinkumi banks, the Rokinren Bank, labor banks, the Prefectural Credit Federation of Agricultural Cooperatives, agricultural cooperatives, the Prefectural Credit Federation of Fishery Cooperatives, and fishery cooperatives from 1988 to 2003.

MF3 includes deposits at domestically licensed banks, Japan Post Bank, Shinkumi banks, labor banks, the Prefectural Credit Federation of Agricultural Cooperatives, agricultural cooperatives, the Prefectural Credit Federation of Fishery Cooperatives, and fishery cooperatives from 2004.

Compared with M3, MF3 after 2004 does not cover demand deposits and time deposits at foreign banks in Japan, the Shinkin Central Bank, *shinkin* banks, or the Norinchukin Bank. Note that MF3 does not include currency, while it includes deposits held by financial institutions other than domestically licensed banks not included in M3.

B. Prefectural Accounts Statistics

The prefectural accounts, which are the prefectural counterpart of GDP, are published by each prefecture. The Cabinet Office of the government of Japan collects data from each prefecture and publishes them around February of each year. As of February

2013, data up to fiscal 2009 are available. Note that the methods of estimation of the prefectural accounts vary from prefecture to prefecture, and thus the sum of the prefectural accounts is not equal to the national accounts.

As of February 2013, there are four series of prefectural accounts data because of differences in the methods of the System of National Accounts (SNA): the 1968 SNA or the 1993 SNA, and the base years. First, from fiscal 1955 to 1974, we have data on the 1968 SNA, with 1980 constant prices. Second, from fiscal 1975 to 1999, we have data on the 1968 SNA, with 1990 constant prices. Third, from fiscal 1990 to 2003, we have data on the 1993 SNA, with fiscal 1995 constant prices. Fourth, from fiscal 1996 to 2009, we have data on the 1993 SNA, with 2000 constant prices .

The Japanese Cabinet Office selects the following series as the official estimates: from fiscal 1975 to 1989, the 1968 SNA with 1990 constant prices , from fiscal 1990 to 1995, the 1993 SNA with 1995 constant prices, from fiscal 1996 to 2009, the 1993 SNA, with 2000 constant prices.

We use the data on nominal GPE, nominal PPC, the deflator for GPE, and the deflator for PPC. We use GPE and PPC in constant prices normalized per capita using the population data from 1995 to 2009 for our explanatory variable of the demand for money.[24]

For the deflator, we use the constant price deflator for GPE. We use the growth rate for prefectural CPI data to estimate the unavailable data series for four areas, Fukushima Prefecture from fiscal 1975 to 1979, Saitama Prefecture from fiscal 1975 to 1976, Okayama Prefecture from fiscal 1975 to 1984, and Okinawa Prefecture from fiscal 1975 to 1980. Since there is a jump in the series in fiscal 1995, 1990, and 1974,

[24] Fujiki and Mulligan (1996b) used prefectural income data and the prefectural CPI for the deflator.

we adjusted the discontinuity by the ratio of estimates in fiscal 1990 and fiscal 1995 for the two series available. Data from fiscal 1955 to 1974 were scaled down by the ratio of fiscal 1980 estimates divided by 100, since we know that the series from fiscal 1955 to 1974 is based on constant prices for 1980.

Deflators for PPC are constructed in a way similar to that for constructing the deflator for GPE; first we estimate the deflator by dividing the nominal series of PPC by a constant price series for PPC, and we use the same method for connecting the discontinuous series and filling in the missing variables using CPI.

Regarding the nominal GPE, since there are two changes in the base years and a jump in the series in fiscal 1995, 1990, and 1974, respectively, we adjusted the discontinuity by the ratio of estimates in fiscal 1990 and 1995 for the two series.

C. Other Conditional Variables

To control the level of financial technology for each prefecture in estimating the empirical model, Fujiki and Mulligan (1996b) used population density and the percentage of net prefectural product explained by primary industry and the prefectural fixed effect. In this paper, we add the percentage of GPE explained by the service industry. We employ the ratio of job offers to the number of job applicants for the instrumental variable as in Fujiki and Mulligan (1996b). We add the proxy variable of population aging, the share of the population aged 65 years or older,to our list of conditional variables.

1. Population density

We compute the population density to take differences in financial services among regions into account as a proxy variable for urbanization. The data use the population of each prefecture reported in the prefectural accounts statistics.

2. Percentage share of primary industry

We compute the percentage share of primary industry (agriculture, forestry, and fisheries) to control differences in financial services among regions as a proxy variable for urbanization. We compute the data by dividing the gross prefectural product explained by primary industry normalized by the gross prefectural product reported in the prefectural accounts statistics.

3. Percentage share of service industry

We compute the percentage share of the service industry to control differences in financial services among regions. We compute the data by dividing the gross prefectural product explained by the service industry normalized by the gross prefectural product reported in the prefectural accounts statistics.

4. Ratio of job offers to the number of job applicants

The prefectural deposit statistics are compiled on the basis of the location of branches. Consider a worker who commutes to his office in the neighboring prefecture, who has his bank account near his office. In this case, his income is counted in the prefecture where he lives, while his deposits are counted in the neighboring prefecture. Such a situation would be quite possible in a large prefecture like Tokyo. If such region-specific financial factors are unobservable and correlated with GPE, one may wish to employ some instrumental variables.

The instrumental variables should correlate with GPE, but should not, however, correlate with other determinants of deposits (such as the degrees of urbanization captured by the population density). The ratio of job offers to applicants is an important indicator of labor market conditions that correlates with short-run fluctuations of income, but one may safely assume that it does not correlate with the long-run changes in the level of financial technology. Hence we employ the ratio of job offers to applicants as our instrumental variable. Available data go back to 1963.

5. Share of the population aged 65 years or older

To control for the effects of population aging, we add the share of the population aged 65 years or older. Statistics are available from fiscal 1970. Theoretically, population aging can increase or decrease the demand for money by households and firms, and thus we should rely on empirical studies to examine which of the two effects dominates. We will discuss the theoretical argument below.[25]

Regarding the effects of population aging on the demand for money by households, the life-cycle model supposes that a young agent saves while a retired old agent reduces his or her savings to pay for consumption. Hence, if the share of the population aged 65 years or older is higher than the share of the working age population (aged from 15 to 64), then the national savings rate will fall. However, in the midst of the process of population aging, high-income old agents may still save, and thus prefectures with an aged population will have more deposits than prefectures with a young population given other determinants of the demand for money such as the level of income. One does not know *ex ante* which of the two effects dominates in the prefectural deposit statistics.

Regarding the demand for money by firms particularly for investment, population aging affects investment through at least two channels. First, if a decrease in the labor force substitutes for capital, domestic investment could increase. If the increased investment is funded by bank borrowing, it is likely that the demand for money increases. Second, a decrease in domestic demand due to the declining population

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[25] The discussion in the following two sections draws on Horioka (2009).

reduces domestic investment and increases foreign investment. Suppose, for example, that a firm stops its domestic investment funded from bank borrowing, and purchases the stock of foreign firms using cash. In such a situation, demand for money by firms would decrease. If population aging shifts consumption toward the service industry and firms find it difficult to substitute labor for capital, the second effect will dominate the first effect given the development of the global capital market. Then, one may well forecast that the population aging reduces the demand for money by firms.

The decomposition of prefectural deposits by households and firms could help infer which effects will dominate; however, such information is unavailable. One can make an educated guess from the breakdowns of the money supply statistics by households and firms that we will see in the next subsection, and we infer from the information that the weight of household deposits in MF2 might have increased.

As discussed in Section II, Fujiki and Mulligan (1996b) do not consider the effects of population aging. However, the effects of population aging could affect the demand for money through various channels. For example, the substitutability of real balance m and goods x_3 could differ for old agents and young agents (for example, young people make use of use online transactions to a greater extent). The level of income or the income distribution may change as population aging proceeds. In this paper, rather than modeling the effects of population aging on the demand for money, we introduce a proxy variable for population aging and empirically examine the bias arising from omitting such a variable.[26]

[26] Nagayasu [2012b] used dependency ratio to examine the effects of population aging on demand for deposits by prefectures.

D. Data Preview

Before moving on to the regression analysis, we discuss some statistical properties of the data used in this paper below.

1. MF1, MF2, and MF3 versus M1, M2, and M3

This section explains the discrepancy between our MF statistics and money stock statistics.

Chart 1 shows the end of fiscal year outstanding amount of M1 and M2, and the prefectural aggregate of MF1 and MF2. We do not include M3 in this chart since we do not have a long time series. Differences between M1, M2, and MF1, MF2 derive from three sources. Namely, MF1 and MF2 do not include currency but include deposits at a limited number of financial institutions compared with money stock statistics, and they include deposits made by financial institutions.

The ratio of MF2 to M2 (**Chart 1**, the dotted line) was fairly stable and took a value around 100% by the 1990s, then fell gradually, and showed a jump in 2003 due to the revision of statistics. The ratio of MF1 to M1 (**Chart 1**, the solid line) was around 70% to 80% from the late 1960s and showed a large jump at the end of the 1980s. The ratio increased somewhat after 2003, perhaps reflecting the continued low interest rate period. This may be related to the shift from time deposits to demand deposits, because the Japanese deposit insurance system virtually ended full protection of bank deposits and protected time deposits only up to ¥10 million. Another question is the extent to which the increase is due to the inclusion of Japan Post Bank in the MF1 statistics since 2003. To answer this question, we have also computed the data series MF1 (old) (**Chart 1**, the dashed line). The MF1 (old) series subtracts the liquid deposits of Japan Post Bank from the MF1 series.[27] As expected, this subtraction reduces the ratio of the MF1 (old) statistics to M1 substantially after 2003.

Chart 2 examines the effects of the omission of currency in MF2. The dashed line in **Chart 2** shows the ratio of currency to M2. The ratio took a value of around 7-8% before 1995, which means that MF2 can predict about 90% of M2. In the era of low interest rates after 1995, the ratio rose to 10% by 2003, and regained stability. Note that such a rapid increase in the demand for currency from 1995 to 2003 can be seen in the rapid increase in the ratio of M1 to M2 shown in the solid line in **Chart 2**.

Finally, **Chart 3** shows the increase in the proportion of demand deposits and time deposits held by individuals. More precisely, M2+CDs in the money supply statistics consist of currency, demand deposits, quasi-money (time deposits), and certificates of deposit. **Chart 3** shows the breakdown of demand deposits and quasi-money by individuals and firms from 1974 to 2007. Regarding demand deposits, which approximate our MF1, before the 1980s firm deposits explain 60% of demand deposits while individual deposits explain 40%. After the end of the 2000s, to the contrary, firm deposits explain 40% of demand deposits while individual deposits explain 60%. Regarding the sum of demand deposits and quasi-money, which approximate our MF2 and MF3, by the end of the 1990s firm deposits explain 40% of the sum of demand deposits and quasi-money, while individual deposits explain 60%. After the end of the 2000s, firm deposits explain only 30% of the sum of demand deposits and quasi-money, while individual deposits explain 70%. It is tempting to argue that the share of individual deposits increases over time, but it is premature to assert this direction

[27] We use the liquid deposits outstanding by prefecture reported in the disclosure report of Japan Post Bank.

because there are two offsetting forces. First, as more of the elderly retire, the share of individual deposits could decrease. Second, as money saving by firms continues, the share of individual deposits could increase. In short, this issue needs to be addressed by empirical studies.

2. Dispersions of MF1, MF2, and MF3

To examine the regional variation of MF1, MF2, and MF3, **Chart 4** shows the dispersion of the data series. In obtaining dispersions, we deflate MF1, MF2, and MF3 for each year by the GPE deflator normalized by the prefectural population, and then compute standard deviations of the log of the series in each year. It is well known that dispersions are almost identical to the coefficient of variation of the original series, and thus this is a useful measure of the regional variation of the per capita real money balance at each point in time.

Chart 4 shows that the dispersions fell in the 1960s (a period of rapid growth in Japan) and the 1970s, and increased somewhat in the late 1980s (a period of real estate bubbles in Japan) but reached a stable value thereafter. The increase in dispersion of MF1 (the thick solid line) from 2001 to 2003 may reflect the continued low interest rates or changes in the Japanese deposit insurance system, as explained above. The dispersion of MF3 (the thin solid line) is always smaller than that of MF2 (the dashed line). Note that MF3 includes deposits at local financial institutions and Japan Post Bank, which makes the weight of the low-income prefectures greater than that of MF2. Therefore, one may safely conclude that the cross-prefectural variation in MF3 is smaller than that of MF2.

3. Dispersions of GPE and PPC

Chart 5 shows the dispersions of real GPE per capita and real PPC per capita. As is well known in the empirical literature on economic growth, the dispersions of real GPE per capita (the thick solid line) converged rapidly by 1974, when the Japanese high-growth period ended. Later, the dispersions increased somewhat in the late 1980s and the mid-2000s. However, in 2009 the dispersion took a value similar to that around the late 1980s. The dispersions of real PPC per capita (the thick dashed line) follow the same trend as that of real GPE per capita, but took smaller values.

4. Correlation between MF2 and GPE

Chart 6 plots the log of real M2 per capita data and the log of gross prefectural product per capita data with a 10-year interval. **Chart 6** shows that MF2 tends to be larger if the gross prefectural product is higher, and as time passes both MF2 and gross prefectural product grow and thus shift to the upper right corner of the graph. Note that the data for Tokyo Prefecture becomes an outlier (takes a large value) each year. For example, the data for 1989, 1999, and 2009 show up in the upper right-hand corner of the chart.

The upper panel of **Chart 7** shows the data up to 1989, the period analyzed by Fujiki and Mulligan (1996b). We see that both the dispersions of gross prefectural product and the slope of the linear trend line each year decrease over time. The lower panel of **Chart 7** shows the data in 1989, the final period analyzed by Fujiki and Mulligan (1996b), and the data in 1999 and 2009. Compared with the upper panel, the growth rate of real gross prefectural product per capita slowed in these periods, and the data for the three periods took similar values. Moreover, the slope of the trend line each year flattened as time passed.

Note that **Chart 7** plots the gross prefectural product in fiscal 1989 with MF2 at the end of fiscal 1989 (namely, March 1990). Therefore, the money demand functions estimated in the following sections correspond to the demand for money measured at the end of the period. Theoretically, it is desirable to estimate the average amount of the demand for money, and we have constructed a proxy for the average amount of MF2 for the 1989 data by averaging the data in March 1989 and March 1990, deflating it and normalizing it by population. The correlation coefficient of a proxy for the average amount of MF2 and our MF2 measured at the end of the fiscal year is 0.99 each year, and the results of regressions are nearly the same except for 1955 and 1956. Hence, we will report the results of regressions using the end of fiscal year data for MF2 in the following sections.

IV. Results of Regressions

Section IV first reports the results of estimation from the time-series data, explains the results of cross-sectional analysis and highlights our benchmark results, and then moves on to show the robustness test of the benchmark results. Before proceeding to the details of the analysis, we summarize here the major results of Section 4.

First, the demand for money based on time-series data estimated from the period between 1955 and 2009 became unstable if we used the sample period after 1990, while it was stable if we used the sample period between 1955 and 1989. The results suggest that it would be useful to cross-check other empirical methods concerning the sample period after 1990.

Second, we explain the results of our estimation of cross-sectional income elasticity of MF2 conditional on population density as the benchmark result. The results in the 1980s are roughly consistent with the results obtained by Fujiki and Mulligan (1996b), who reported that the income elasticity conditional on the percentage share of primary industry took values around 1.2 and 1.4. Our results using the sample period after the 1990s showed that the income elasticities decreased gradually over time and were statistically differed significantly from zero. These results are robust to the inclusion of additional explanatory variables and the use of pooling regression analysis.

A. Results of Estimation from Time-Series Data

To illustrate the difficulty of estimating the demand for money using the Japanese time-series data, we show an example of time-series estimation using the same sample period of our cross-sectional data, from 1955 to 2009. In particular, we regress the log M2 per capita deflated by the GDP deflator on the log real GDP per capita and nominal interest rate to compare our cross-sectional estimates using per capita real MF2 in the remaining sections. We use the annual yield of five-year interest-bearing bank debentures from 1965 to 2009 for the interest rate, which comprises the longest available long-term interest rate data.

Compared with the cross-sectional structural model defined in equation (11), this time-series estimation regards the variables after the second line of the right-hand side of the equation as a constant term. Note that the interest rate elasticity in equation (11) is defined in terms of the log of gross nominal interest rates, but this variable is almost equal to the percentage interest rate divided by 100. Therefore, by multiplying by 100, the interest rate elasticity obtained from the following time-series regression corresponds to the estimates of the structural parameter γ in equation (11).

We begin by our estimation with unit root tests for M2, GDP, and interest rates. As the top panel of **Chart 8** shows, we cannot reject the null hypothesis that the variables have unit roots by the standard augmented Dickey-Fuller Test (Dickey and

Fuller [1979, 1981]).

The middle panel of **Chart 8** shows the results of time-series estimations. The first row shows the results of regressing the log real per capita M2 on the log real per capita GDP, and the second row shows the results of regressing the log real per capita M2 on the log real per capita GDP and interest rates. The estimates of income elasticities (measured by real per capita GDP) took values of 1.45 and 1.32, consistent with the Japanese literature using the M2+CD data up to the 1990s. Unfortunately, since the independent variables have unit roots, the standard errors reported here do not follow the normal distribution, and thus we do not know whether the estimates statistically differ significantly from zero. Moreover, the residuals from the regressions reported in the first and second rows of the panel seem to have serial correlation as shown by the Durbin-Watson statistics and seem to have unit roots as a result of the augmented Dickey-Fuller test in the seventh to eighth columns, hence we cannot argue that the parameter estimates are the cointegrating vector. Therefore, the results in the first and second rows in the middle panel of **Chart 8** do not show the cointegrating vector but show spurious correlations (Engel and Granger [1987]).

As a simple remedy for the spurious correlations due to the existence of unit roots, the third and fourth rows of the middle panel of **Chart 8** show the results of the regressions taking the difference of the variables used in the first and second rows. The estimates of income elasticities are 0.85 to 0.89, and the interest rate elasticity is 1.36. The results of the augmented Dickey-Fuller test reported in the sixth to eighth rows suggest that the residuals of the two regressions are stationary, and thus the elasticities statistically differ significantly from zero. While we may safely say that the difference specification gives us more reliable estimates than the level specification, it is a question whether the constant terms in the difference specification are positive and statistically differ significantly from zero. Taken literally, the results suggest that there is a linear trend in the level specification. This finding is consistent with the convention that researchers introduce a linear time trend as an additional independent variable as a proxy for financial innovation in estimating the long-run time-series demand for money, for example, McCallum and Nelson (2011, p. 109).

Note that Japanese time-series data often show large kinks in their trend around the period after the increase in the oil price in the early 1970s and the collapse of the real estate bubbles in Japan in the early 1990s. The major contribution of this paper lies in the extension of the sample period from 1955 to 1989 to 1955 to 2009, and thus we split the sample period in 1989. The results are reported in the third panel of **Chart 8**. The results using difference variables show that the estimates using data from 1955 to 1989 are similar to the estimates using data from 1955 to 2009, but the estimates using the data from 1989 to 2009 show statistically insignificant estimates of income and interest rate elasticities whose signs are opposite those of the theoretical model.[28] Do we encounter a similar problem in our cross-sectional estimates? We move on to explain the results from the cross-sectional data from the next subsections.[29]

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[28] The empirical relationships for Japanese M1 obtained from the sample period before 1990 are not robust to the addition of sample data for the period after the 1990s. McCallum and Nelson (2011, pp. 125–127) report that they cannot reject the null hypothesis that a 1 percentage point increase in M1 leads to a 1 percentage point increase in the rate of price increase using the samples before 1989 (they omit the data in 1974, when Japan experienced very high inflation); however, they find that that a 1 percentage point increase in M1 leads to at most a 0.4 percentage point increase in the rate of price increase using the samples by adding data from 1990 to 2008. They infer that the demand for M1 increased substantially due to the period of low interest rates in Japan.

[29] We split the sample period in 1989 to examine the effects of extending the sample period from 1955 to 1989 to 1955 to 2009. One might wish to determine the timing to split the sample period using the unit root tests that incorporate the effects of structural changes. One might also wish to determine the timing

B. Results of Cross-Sectional Regressions: Benchmark Results

1. Empirical model

We estimate equation (12) below following Fujiki and Mulligan (1996b) as our empirical model of the theoretical model shown as equation (11).

$$\log(\frac{MF2_{it}}{P_{it}N_{it}}) = a0_t + a1_t \log(\frac{GPE_{it}}{P_{it}N_{it}}) + a2_t Z_{it} + e_{it}. \qquad \textbf{(12)}$$

We use data from 1955 to 2009, and we focus the results using MF2 deflated by the GPE deflator and normalized by the prefectural population as a dependent variable, which is a counterpart of M2, as can be seen on the left-hand side of equation (12). Note that *P* is the GPE deflator, *N* is the prefectural population, subscript *i* shows the prefecture and subscript *t* shows the time period. We call the dependent variable as the log of real MF2 per capita hereafter.

The first term on the right-hand side of equation (12) shows the constant term, which takes a different value for each year. The term absorbs the effects of interest rates and relative prices that are common to each prefecture at a given time period. The second term shows the log of per capita real GPE (hereafter the log of real GPE per capita). The third term, *Z*, is a vector for the proxy variables for the weighted average of the level of transaction technology by households and firms in each prefecture. It includes population density, the percentage of gross prefectural product explained by primary industry, the percentage of GPE explained by the service industry, and the

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of the structural changes in the parameters of money demand functions through various statisistical tests. These exercises are left for future study.

share of the population aged 65 years or older. The fourth term, *e*, comprises independently distributed statistical error terms.

Although equation (11) shows that the per capita real money balance also depends on the number of firms and households, the share of the firm income relative to household income, and the variance of income distribution, we do not include these variables because the prefectural breakdown of these variables is hard to obtain.

2. Results of univariate regression and multiple regressions

We begin with cross-sectional estimates of the elasticity of money demand to GPE without adding any other conditioning variables. The thick solid line in **Chart 9** shows the estimated income elasticities in each fiscal year by using the log of real MF2 per capita as a dependent variable and the log of real GPE per capita as an independent variable. The estimates of univariate income elasticities take the same value as the slope of the regression line in **Chart 6**, and thus we expect that the estimates take positive values.

Chart 9 shows that the univariate cross-sectional estimates of the elasticity of money demand to GPE move around 1.5 to 2.0 and fall over time after the 1980s, as we saw in the upper panel of **Chart 7**. The estimates are slightly smaller than the univariate income elasticities of money demand to the log of prefectural income deflated by the prefectural CPI, which take values from 1.9 to 2.6, from the same period of time obtained by Fujiki and Mulligan (1996b). The cross-sectional univariate estimates of the elasticity of money demand to GPE fall over time in the sample period after the 1990s and take a value around 1.1.

Chart 9 also shows the cross-sectional estimates of the elasticity of money demand to GPE conditional on the four proxy variables for the weighted average of the level of transaction technology as an additional independent variable: population density (the thin solid line), the percentage of gross prefectural product explained by primary industry (the thin dashed line), the percentage of GPE explained by the service industry (the thick dashed line), and the share of the population aged 65 years or older (available only after 1970, the thick dashed and dotted line).

Chart 9 shows the cross-sectional estimates of the elasticity of money demand to GPE conditional on the percentage of GPE explained by the service industry (the thick dashed line) are similar to the univariate elasticity. The addition of the share of the population aged 65 years or older (the thick dashed and dotted line) yields a slightly smaller elasticity of money demand compared with the univariate elasticity. These results do not necessarily mean that there is no effect of population aging on the demand for money; instead, the results may suggest that several effects from population aging offset each other or that the effects from the other missing variables contaminate the results.

Chart 9 also shows that the cross-sectional estimates of the elasticity of money demand to GPE conditional on population density (the thin solid line) or conditional on the percentage of gross prefectural product explained by primary industry (the thin dashed line) yield lower estimates compared with the univariate estimates. These findings suggest that the elasticity of money demand to GPE might be overestimated if differences in the level of transaction technology across prefectures are omitted.

3. Benchmark results from the multiple regressions

Chart 10 provides details on a result reported in the previous section: the estimated income elasticities by regressing the log of real MF2 per capita on the following sets of in dependent variables: a constant term, the log of real GPE per capita, and population density. Specifically, the thick solid line stands for income elasticities, the thick dashed line stands for the lower bound of the confidence interval for income elasticities evaluated at the 95% level (constructed by subtracting the standard error of the estimates multiplied by 2.01 from the estimated parameters in each year), the thin dashed line shows the interest rate elasticities, and the thin solid line shows the lower bound of the confidence interval for interest rate elasticities evaluated at the 95% level.

Fujiki and Mulligan (1996b) obtained a cross-sectional income elasticity of money demand to prefectural income of around 1.2 to 1.4 after controlling for the percentage of net prefectural product explained by primary industry. Our cross-sectional income elasticity of money demand after controlling for the population density yields estimates that are similar to their results for the sample period between 1955 and 1989 (the thick solid line). Our estimates of income elasticities fall over time after the 1990s, and the lower bound of the elasticities (the thick dashed line) shows that they are statistically significantly larger than zero. The estimates of elasticities of money demand to population density are positive (the thin solid line), and statistically significantly larger than zero (the thin dashed line) except for the sample period of 1956, 1958, from 1961 to 1964, and from 1967 to 1973 .

Chart 11 shows another way to view the evolution of income elasticities from 1955 to 2009. Specifically, the horizontal axis shows the residual from the regression using the log of real GPE per capita as a dependent variable and population density as an independent variable. The vertical axis shows the residual from the regression using the log of real MF2 per capita as a dependent variable and population density as an independent variable. We show the results of cross-sectional regressions in the sample years 1969, 1979, 1989, 1999, and 2009. The trend line in the chart corresponds to the partial correlation coefficient between the log of real MF2 per capita and the log of real GPE per capita holding after controlling for the population density, whose slopes correspond to the size of the cross-sectional estimates of income elasticity reported in the thick solid line in **Chart 10**. Note that we plot the regression residuals whose mean is zero, and we do not observe the tendency that the level of data increases over time as we saw in the plot of **Chart 7**.

The upper panel of **Chart 11** shows that the partial correlation coefficients are stable and take a value around 1.2 to 1.5. The lower panel shows that the partial correlation coefficients fall over time and, compared with the data in 1989, the demand for money in the relatively low-income prefectures (after controlling for the population density) increases, and thus the slope of the trend lines flattens over time.

Note that the cross-sectional income elasticity of money demand conditional on the percentage of gross prefectural product explained by primary industry is similar to our results above; however, the standard errors for the income elasticities increased substantially after 2004, which makes the estimates of income elasticity not statistically significantly different from zero. Therefore, we choose the estimated income elasticities by regressing the log of real MF2 per capita on the following three independent variables: a constant term, the log of real GPE per capita, and population density, which are consistent with the estimates by Fujiki and Mulligan (1996b), as our benchmark results.

4. Adding some conditional variables

Chart 12 compares the cross-sectional estimates of the elasticity of money demand to GPE conditional on population density (the thick solid line), and the cross-sectional estimates of income elasticity of money demand to GPE conditional on population density and one more variable: the percentage of gross prefectural product explained by primary industry (the thin dashed line), the percentage of GPE explained by the service industry (the thick dashed line), and the share of the population aged 65 years or older (the thin solid line). The addition of the percentage of GPE explained by the service industry to the independent variable does not alter the size of the estimates of income elasticities, while the addition of the percentage of gross prefectural product explained by primary industry and the share of the population aged 65 years or older to the independent variable reduces the estimates of income elasticity by 0.1 to 0.2 in their absolute values (the thin solid line). The income elasticities fall over time, consistent with our benchmark results.

5. Pooling regressions

To see the average trend of the cross-sectional regressions, we report the results of pooling regressions that assume the constant terms take different values each year while the parameters for the other conditioning variables take a common value during the sample period, shown as equation (13). Equation (13) and equation (12) differ on two points: the slope terms *b1* and *b2* are constant in the sample period, and thus they do not have subscript *t*.

$$\log\left(\frac{MF2_{it}}{P_{it}N_{it}}\right) = b0_t + b1\log\left(\frac{GPE_{it}}{P_{it}N_{it}}\right) + b2Z_{it} + e_{it}. \qquad \textbf{(13)}$$

Chart 13 reports the results of pooling the entire sample period from 1955 to 2009 and the subsamples after 2004 taking into account the discontinuity in prefectural deposit statistics used in the analysis. The analyses using the share of the population aged 65 years or older are constrained after 1970 due to the limitation in the data.

The pooling estimates generally yield estimates of income elasticity of around 1 to 1.5 using the sample period from 1970 to 2003, and the addition of the share of the population aged 65 years or older does not alter the estimates of income elasticities if we control for other explanatory variables. The additions of the percentage of GPE explained by the service industry tend to increase the income elasticities in all of the specifications. The data after 2004 tend to yield lower income elasticities of money demand, around 0.6 to 1.0, compared with the same specification of the regressions using the data from 1970 to 2003. This tendency is consistent with the benchmark results.

V. Possible Measurement Errors Arising from Prefectural Deposits

The prefectural deposit statistics are compiled on the basis of the location of branches. Consider, for example, a worker who lives in prefecture A and commutes to his office in neighboring prefecture B, and who has a bank account near his office. In this case, his income is counted in prefecture A while his deposits are counted in prefecture B. Given this method of compiling the prefectural deposit statistics, such out-of-prefecture deposits imply that the income in prefecture A is measured inaccurately. Does this consideration of such a measurement error affect our analysis thus far?

In this section, we analyze four ways to deal with such a measurement error. Three of them follow Fujiki and Mulligan (1996b). First, we drop the prefectures with large cities from the sample by assuming that most of the out-of-prefecture deposits are centered in such prefectures where many commuters from neighboring prefectures work. Second, we introduce prefectural fixed effects by assuming that the distributions of out-of-prefecture deposits reflect the geographic and historical nature of prefectures. Third, we use instrumental variables for GPE by assuming that out-of-prefecture deposits reflect the unobservable prefecture-specific level of financial technology, which is correlated with GPE. Fourth, we use a dynamic panel model by assuming that the lagged independent variables predict some of the effects of out-of-prefecture deposits. We will discuss these analyses in turn.

A. Dropping Tokyo Prefecture from the Sample

Chart 14 shows the cross-sectional estimates of the elasticity of money demand to GPE after dropping the data for Tokyo Prefecture from our sample. The thick solid line shows the elasticities from the univariate regressions, the thick dashed line shows the elasticities also controlling for the percentage of GPE explained by the service industry, the thin dashed line shows the elasticities also controlling for the percentage of gross prefectural product explained by primary industry, and the thin solid line shows the elasticities also controlling for the population density.

The estimates of income elasticities from the univariate regressions fall over time, and the level of these elasticities is somewhat lower than their counterparts estimated from the sample including Tokyo Prefecture. The qualitative nature of the results is similar to the results obtained by Fujiki and Mulligan (1996b). The size of the estimates of income elasticities from the multiple regressions is also smaller than those obtained from the sample including Tokyo; however, perhaps reflecting the discontinuity in prefectural deposit statistics, some of the elasticities take a negative value and do not statistically differ significantly from zero.

We also use a sample dropping other prefectures that might have a large amount of out-of-prefecture deposits, such as Osaka, Kanagawa, and Kyoto prefectures in addition to Tokyo. The results of the regressions using these samples of prefectures yield results similar to those reported above.

B. Adding Prefectural Fixed Effects

Suppose that the distributions of out-of-prefecture deposits reflect the geographic and historical nature of prefectures. Then, we may safely assume that such effects can be captured by the prefectural fixed effects that are independent of the level of income in each prefecture. The use of a fixed-effects model requires us to pool observations for several years. In determining the sample periods of pooling observations, for the sake of comparing the results obtained in the previous sections, we choose the same sample periods used in the pooling analysis in **Chart 13**, and add prefectural effects as an explanatory variable Z in the equation in the results reported there. The results appear in **Chart 15**.

Chart 15 shows that the pooling estimates of the elasticity of money demand to GPE conditional on prefectural fixed effects take a smaller value compared with the pooling estimates controlling for the same independent variables reported in **Chart 13**. For example, multiple regressions using data from 1955 to 2003 with prefectural fixed effects yield pooling estimates around 0.6 to 0.8, compared with the pooling estimates without prefectural effects, which yield estimates of 1.2 to 1.4. The results are consistent with the finding of Fujiki and Mulligan (1996b). Multiple regressions using data from 2004 to 2009 with prefectural fixed effects yield pooling estimates around 0.3 to 0.4, compared with the pooling estimates without prefectural effects, which yield estimates of 0.6 to 0.7.

We must be careful about the downward bias for the estimates with prefectural fixed effects. For example, such a downward bias is well known if there is a random measurement error in the gross prefectural product (Griliches and Hausman [1986]).

To grasp this point, consider equation (14) below, which supposes that prefectural fixed effects are the sole variables in vector Z_i.

$$\log(\frac{MF2_{it}}{P_{it}N_{it}}) = b0_t + b1\log(\frac{GPE_{it}}{P_{it}N_{it}}) + Z_i + e_{it}\,. \qquad \textbf{(14)}$$

In equation (14), *GPE* on the right-hand side represents the ideal gross prefectural product, which is compiled on the basis of the prefectural deposit statistics. In this ideal statistics, if a worker lives in prefecture A and has deposits in prefecture B, his income is counted in prefecture B. What we want to do is estimate the income elasticity of money demand with respect to the gross prefectural product using this kind of ideal statistics. In practice, we can only use GPE^*, which is the sum of ideal data, *GPE*, plus a measurement error v_{it}, which are independently and normally distributed as shown below in equation (15).

$$\log(\frac{GPE_{it}^{\ *}}{P_{it}N_{it}}) = \log(\frac{GPE_{it}}{P_{it}N_{it}}) + v_{it}\,. \qquad \textbf{(15)}$$

Therefore, we can only estimate the following regression equation (16) in practice:

$$\log(\frac{MF2_{it}}{P_{it}N_{it}}) = \overline{Z} + b0_t + b1\log(\frac{GPE_{it}}{P_{it}N_{it}}^{*}) - b1v_{it} + e_{it} + (Z_i - \overline{Z}), \qquad \textbf{(16)}$$

where the last term on the right-hand side, $(Z_i - \overline{Z})$, stands for the out-of-prefecture deposits that are absorbed in the prefectural fixed effects. In this way, the bias due to the correlation between the out-of-prefecture deposits and GPE^* is absorbed in the prefectural fixed effects. It might be wondered whether the estimates of income elasticities, *b1*, obtained from equation (16) are reliable compared with the income elasticities reported in our benchmark results. Unfortunately, the estimates of income elasticities, *b1*, obtained from equation (16) may not be reliable compared with the income elasticities reported in our benchmark results because equation (15) shows that the third term, GPE^*, and the fourth term, $-b1v_{it}$, in equation (16) are negatively correlated, and thus the parameter estimates of *b1* in equation (16) have a downward bias (Griliches and Hausman [1986, p. 94]).

C. Instrumental Variables for GPE

One might well assume that out-of-prefecture deposits reflect the unobservable prefecture-specific level of financial technology, which is correlated with GPE. Specifically, the first line of equation (17) shows the observable money demand function, whose error term, e_{it}, consists of the measurement errors v_{it}, which are independently and normally distributed, and the linear function of unobservable financial technology in each prefecture, F_i, as shown in the second line of equation (17) (note that θ is a parameter).

$$\log\left(\frac{MF2_{it}}{P_{it}N_{it}}\right) = b0_t + b1\log\left(\frac{GPE_{it}}{P_{it}N_{it}}\right) + e_{it}\,. \qquad \textbf{(17)}$$

$$e_{it} = F_i\theta + v_{it}\,.$$

Unobservable financial technology in each prefecture, F_i, should have a positive correlation with GPE because the level of income in prefectures with a large amount of out-of-prefecture deposits made by commuters from neighboring prefectures could be high. Therefore, estimation of equation (17) by ordinary least squares (OLS) could yield upwardly biased estimates of *b1* because F_i in the error terms has a positive correlation with GPE_i.

A remedy for this problem is the use of instrumental variables. The instrumental variables should correlate with GPE, but they should not correlate with the unobservable financial technology in each prefecture, F_i, or the error term v_{it}. We use the ratio of job offers to the number of job applicants as the instrumental variable. The ratio of job offers to the number of job applicants is an important indicator of labor market conditions that is correlated with short-run fluctuations in income; however, we may safely assume that it is not correlated with long-run changes in the unobservable financial technology in each prefecture, F_i.

We apply two-stage least squares (2SLS) methods to use the instrumental variable estimation methods. We first predict the log of real GPE per capita using the ratio of job offers to the number of job applicants and other explanatory variables, except for the log of real GPE per capita using OLS. Then we use the predicted value of the log of real GPE per capita as the instrumental variable for the log of real GDP per capita in equation (17) to apply the 2SLS methods.

We try to use the same sample period that we used in the pooling estimation, equation (13). However, since the data on the ratio of job offers to the number of job applicants are available only after 1963, we report the results using the sample period from 1963 to 2003 and the sample period from 2004 to 2009 in **Chart 16**. We report the results of estimation by the instrumental variable methods, and by OLS, and the first-stage regressions for the log of real GPE per capita to construct the instrumental variable.

We begin with the results using the sample period from 1963 to 2003. In **Chart 16**, the first panel shows that the pooling estimates of income elasticities to GPE obtained by OLS range from 1.1 to 1.6, while the second panel shows that the estimation using the instrumental variable methods yields parameter estimates ranging from 0.5 to 0.7. Second, using the sample from 2004 to 2009, the pooling estimates of income elasticities to GPE obtained by OLS range from 0.6 to 1.1 (the fourth panel), while the estimation by the instrumental variable methods yields parameter estimates ranging from 0.3 to 0.4 (the fifth panel). The finding that the use of instrumental variable methods tends to yield smaller income elasticities of money demand to GPE than the OLS methods with the same control variables is consistent with the results reported in Fujiki and Mulligan (1996b).

However, we should not place too much emphasis on the results based on the instrumental variable methods due to the following results that go against the theoretical and statistical predictions. For example, in the sample period from 1963 to 2003, the percentage of GPE explained by the service industry yields negative coefficients, contrary to the theoretical requirements when we use instrumental variable methods. In the sample period from 2004 to 2009, the percentage of GPE explained by the service industry does not yield statistically significant parameter estimates in the first-stage regressions (the sixth panel in **Chart 16**).

D. Fixed Effects and Lagged Dependent Variables

In Section V.B, we supposed that the out-of-prefecture deposits reflect the geographic and historical nature of prefectures are captured by fixed effects, while in Section V.C we supposed that they are random variables, which are derived from the unobservable prefecture-specific level of financial technology and correlated with GPE. In this section, we assume that a part of the out-of-prefecture deposits can be systematically predicted by the past value of the prefectural deposits, assuming that the geographic and historical nature of prefectures changes gradually over time. These assumptions mean that we should add the lagged dependent variables to the fixed-effects estimation.

This empirical method appears to be promising, but as explained by Angrist and Pischke (2009, p. 245), the estimation done with OLS methods yields biased estimates for the parameters, because the lagged dependent variables are correlated with the contemporaneous error terms. Hence, we use the estimation proposed by Arellano and Bond (1991) in the Stata 10 package. In our estimation, we also include the annual yield of five-year interest-bearing bank debentures from 1965 to 2009 in the independent variables. Since the estimation needs two period lags and the first difference of the variables, the sample periods start from 1967. (If we include the share of the population aged 65 years or older, the sample periods start from 1972.)

The first panel in **Chart 17** shows the results of estimation using the statistical methods proposed by Arellano and Bond (1991). The sum of the coefficients on the lagged dependent variable and GPE is about one, and the implied long-run income elasticities of money demand to GPE reported in the column labeled "Long-run elasticity" range from 0.9 to 1.1.[30] The second panel in **Chart 17** shows that the parameter estimates for the share of the population aged 65 years or older become negative and statistically significant, the parameter estimates for the percentage of GPE explained by the service industry become negative (contrary to the theoretical prediction) and statistically significant, and the parameter estimates for the population density do not become statistically significant. Finally, the implied long-run income elasticities of money demand to GPE reported in the last column range from 1.1 to 1.3. The parameter estimates lie between the benchmark and the results in the three subsections above.

Note that the statistical methods proposed by Arellano and Bond (1991) suppose that the error terms have no serial correlations. One can test this assumption with test statistics proposed by Arellano and Bond (1991), and in our estimation above the assumption is rejected. To cope with this problem, we report the results of estimation methods proposed by Arellano and Bover (1995) and Blundell and Bond (1998) in the third and fourth panels of **Chart 17**. We obtain nearly the same parameter estimates for the lagged dependent variables and the log of GDP per capita by employing these methods.

Note that the methods we have used above do not assume the panel data with long time-series dimensions, and thus these results should not be taken literally (see Kitamura [2005]). For example, the methods from Arellano and Bond (1991) yield statistically insignificant income elasticities of money demand to GPE if the sample of five years is used after the 1990s. Based on these results, the methods above do not

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30 Long-run income elasticity = parameter estimates for the log GPE per capita/(1 – parameter estimates for the lagged dependent variable).

give us statistically reliable evidence for the estimates of income elasticities of money demand using the data for recent periods, and neither do the time-series estimates.[31]

E. Summary

Given the method for compiling the prefectural deposit statistics, out-of-prefecture deposits imply that the income in some prefectures could be measured with error. We analyze four ways to deal with such a measurement error. The first three methods (dropping the prefectures with large cities, adding prefectural fixed effects, and using instrumental variables) tend to yield a lower elasticity of money demand to the log of GPE per capita than the comparable cross-sectional or pooling estimates. One should not take these results literally because these methods require strict assumptions, some of them give an inherent downward bias to the parameters, and the performance of first-stage regression for the instrumental variable methods are not very good. The range of parameter estimates from the dynamic panel model looks plausible; however, the statistical conditions to justify these methods are not warranted in our data sets.

Given these robustness checks, one may conclude that the cross-sectional estimates of income elasticities to money demand with respect to the log real GPE per capita take a larger value than one using the sample period of the data before the 1990s, and take a smaller value than one in the sample period of data after 2000. However, the different methods for estimation could yield income elasticities to money demand with respect to the log real GPE per capita that take a lower value than one even using the sample

[31] One may also use the unit root test and cointegration test for panel data, and apply the dynamic OLS model for our data. See estimation of demand for demand deposit and time deposit from 1990 to 2005 in Nagayasu [2012a], and demand for M1 using cross-country panel data from nineteen economies in Nelson and Sul [2003]. Such an extension is left for the future.

period of data before the 1990s.

VI. Robustness to the Alternative Scale Variable

In this section, we replace the log of real GPE per capita with the log of real PPC per capita in our estimation for the demand for money to examine the robustness of our results obtained thus far.

The transaction theories following Baumol and Tobin stress the relationship between income and the demand for money, while the permanent income hypothesis following Friedman emphasizes the relationship between the level of assets (permanent income) and the demand for money. Meltzer (1963b) argued that empirical analysis should determine the plausibility of these two contrasting theories.[32]

Equation (6) in this paper also suggests that consumption, rather than income, should be the scale variable in the demand for money. One might also argue that if the subjective discount rate is constant and the utility function is a quadratic function of consumption, the level of consumption is proportional to permanent income, and thus the use of consumption for the scale variable for the demand for money corresponds to the empirical implementation of the hypothesis of Friedman.

A. Results of Cross-Sectional Regressions

Chart 18 compares the univariate cross-sectional elasticities of the demand for money

[32] Meltzer (1963b) found that the explanatory power of the money demand function is higher if controlling income for M1 and wealth for M2, and that wealth is the only statistically significant explanatory variable for M2 if controlling both income and wealth using the U.S. time-series data from 1900 to 1950. Goldfeld (1976) pointed out the instability of the demand for money after the sample period of the late 1970s, and Mankiw and Summers (1986) argue that consumption does a better job of predicting the demand for money empirically even including the data in these periods.

with respect to the log of real PPC per capita (the thick solid line) and those with respect to the log of real GPE per capita (the thin solid line). The estimates for these two elasticities take a very similar value by the mid-1970s, and thereafter the PPC elasticities take a larger value than the GPE elasticities. The GPE elasticities fall over time, while the PPC elasticities are stable around 1.9. The thick dashed line stands for the lower bounds of the confidence interval for the PPC elasticities evaluated at the 95% level. Their values are larger than zero. However, the bounds of the confidence interval for the GPE elasticities evaluated at the 95% level, shown by the thin dashed lines, include the parameter estimates of the PPC elasticities except for the late 1980s and the period after the mid-1990s. In this sense, the estimates for these two elasticities do not differ greatly from each other in size.

Chart 19 compares the cross-sectional elasticities of the demand for money with respect to the log of real PPC per capita (the thick solid line) also conditional on population density and those with respect to the log of real GPE per capita also conditional on population density (the thin solid line). The PPC elasticities take a lower value than the GPE elasticities by 1984, and thereafter a larger value than the GPE elasticities by 2003. The GPE elasticities fall over time, while the PPC elasticities are stable by 2003.

After 2004, the thick dashed line, which stands for the lower bounds of the confidence interval for the PPC elasticities evaluated at the 95% level, takes a value below zero.

However, the bounds of the confidence interval for the GPE elasticities evaluated at the 95% level, shown by the thin dashed lines, include the parameter estimates of the PPC elasticities except for the period of 1957 to 1959, 1967 to 1972, and 1999 to 2002.

In this sense, the estimates for these two elasticities do not differ greatly from each other in size.

B. Pooling Regressions

In the hope that the elasticities of money demand with respect to the real PPC per capita are stable, we report the results of pooling regressions in **Chart 20**. To compare with the results reported in **Chart 13**, we focus the results for the subsample from 1955 to 2003 and the subsample from 2004 to 2009 in the third, fourth, fifth, and sixth panels in **Chart 20**. These panels show that univariate elasticities with respect to PPC take a larger value than the univariate elasticities with respect to GPE, and the multiple regressions yield lower PPC elasticities than the GPE elasticities in the first subsample and higher PPC elasticities than the GPE elasticities in the second subsample. These results confirm our findings in Section VI.A.

The parameter estimates for the share of the population aged 65 years are not statistically significant if one controls only for the log of real PPC per capita, while the addition of other independent variables tends to yield somewhat higher PPC elasticities than the same specification without the share of the population aged 65 years. (The exception is the sample period from 2004 to 2009, with the control for the percentage of GPE explained by the service industry.)

C. Summary

The cross-sectional elasticities of the demand for money with respect to the log of real PPC per capita appear to be stable over time compared with the cross-sectional elasticities of the demand for money with respect to the log of real GPE per capita, controlling for the common explanatory variables. However, the bound of the GPE elasticities evaluated at the confidence interval at 95% includes parameter estimates of the PPC elasticities for most of the sample period. In this sense, the estimates for these two elasticities do not differ greatly from each other in size, and thus the results obtained from the log of real GPE per capita are robust to use of the alternative scale variable.

VII. Robustness to the Alternative Deposit Statistics

In this section, we replace the log of real MF2 per capita with the log of real MF1 and MF3 in our estimation for the demand for money to examine the robustness of our results obtained thus far following Meltzer (1963b).

Meltzer (1963b) found that the explanatory power of the money demand function is higher if controlling income for M1, and if controlling wealth for M2. Unlike Meltzer (1963b), we must be careful about the statistical properties of MF1 and MF2 originating from the coverage of different depository institutions. Below we begin by explaining these points and then move on to report the results of regressions using MF1 and MF3 as dependent variables.

A. MF1/MF2, MF3/M2, and GPE

Chart 21 shows the correlation coefficient between logMF2/logMF1 and the log of real GPE per capita in the thick solid line, and the correlation coefficient between logMF3/logMF2 and the log of real GPE per capita in the thick dashed line. Note that the sample correlation coefficients are statistically significantly different from zero if the absolute value of the estimates exceeds 0.29 (the thin dashed line), and thus the results of estimation plotted below this line are statistically significant.[33]

The thick solid line shows that correlation coefficients between logMF2/logMF1 and the log of real GPE per capita are negative and statistically significant before 1985. That is, MF2/MF1 is high in prefectures with low GPE and low in prefectures with high GPE. The results seem to reflect the fact that MF1 includes liquid deposits in the high-income prefectures, because MF1 covers depository institutions whose branches are mainly located in the urban areas.

The thick solid line shows that correlation coefficients are not statistically significant by 2003; however, they become negative and statistically significant after 2004 (**Chart 21**, circled area). This may reflect the inclusion of Japan Post Bank for MF1 after 2004.

The thick dashed line, which represents the correlation coefficients between logMF3/logMF2 and the log of real GPE per capita, shows that the coefficients are statistically significantly different from zero for the period from 1955 to 2009. Note that the major difference between MF2 and MF3 is that MF3 also covers the deposits at Japan Post Bank, agricultural cooperatives, and fishery cooperatives. These institutions accept deposits from individuals in rural areas, and thus they are not very sensitive to changes in the log real GPE per capita. The correlation coefficients gradually fall over time and there is a jump in 2004, which may reflect the exclusion from MF2 and MF3 of deposits at Shinkumi banks.

B. Results Using MF1 as a Dependent Variable

[33] We construct the boundary using the following test statistics. Under the null hypothesis that the population correlation coefficient is zero, the statistics for the sample correlation coefficient *r*, $t = r\sqrt{n-2}/\sqrt{1-r^2}$, follow the t-distribution with the degrees of freedom $n - 2$ with the sample size *n*.

Chart 22 compares the univariate cross-sectional elasticities of demand for MF1 with respect to the log of real GPE per capita (the thick solid line) and the univariate cross-sectional elasticities of demand for MF2 with respect to the log of real GPE per capita (the thin solid line).

Note that MF1 includes the liquid deposits in high-income prefectures because it covers depository institutions whose branches are mainly located in urban areas compared with MF2, and MF1 also includes deposits made by financial institutions. Therefore, we expect that the MF1 cross-sectional elasticities took a higher value than the MF2 cross-sectional elasticities, and we find such results from the data by the mid-1980s, which is consistent with the analysis in **Chart 21**. The thin dashed line in **Chart 22** stands for the upper bound of the confidence interval for the MF2-cross sectional income elasticities evaluated at the 95% level, and the MF1 cross-sectional elasticities exceed the upper bound only prior to the sample period of 1972.

The univariate cross-sectional elasticities of demand for MF1 and MF2 are nearly the same in the sample period after the 1990s. Note that MF1 (old), which subtracts the deposits at Japan Post Bank shown in the thick dashed line after 2004, reports cross-sectional elasticities of demand for MF1 (old) that are higher by 0.1 to 0.2 in their absolute values compared with those obtained from MF1.

Chart 23 compares the cross-sectional elasticities of demand for MF1 with respect to the log of real GPE per capita also conditional on population density (the thick solid line) and the cross-sectional elasticities of demand for MF2 with respect to the log of real GPE per capita also conditional on population density (the thin solid line). When population density is added to the list of independent variables, the cross-sectional elasticities of demand for MF1 not only fall over time but also take values similar to the cross-sectional elasticities of demand for MF2 from the mid-1960s. The thin dashed lines stands for the bound of the confidence interval for the MF2 cross-sectional elasticities evaluated at the 95% level, and the MF1 cross-sectional elasticities lie within the bound only before the sample period of 1959. In the sample period after 2000, the two cross-sectional elasticities should be closer given the higher substitutability between demand deposits and savings deposits reflecting the period of low interest rates, and given the shift from time deposits to demand deposits. This is because in 2003 the Japanese deposit insurance system virtually ended the full protection of bank deposits and protected time deposits only up to ¥10 million. These analyses show that the results obtained from MF2 are robust to the change of the dependent variable to MF1.

Chart 24 reports the results of pooling regressions that attempt to reproduce the analysis of MF2 reported in **Chart 13**. MF1 has an additional statistical discrepancy in 1988 due to the change of mutual banks into domestically licensed banks, and thus we split the sample period from 1959 to 1988, 1970 to 1988, 1989 to 2003, and 2004 to 2009. As expected based on the results from the cross-sectional analyses, the pooling elasticities of MF1 take values that are larger by 0.2 to 0.5 in their absolute values than those of MF2 from the sample period from 1970 to1988, and the pooling elasticities of MF1 and MF2 are close in the sample from 2004 to 2009.

C. Results Using MF3 as a Dependent Variable

Chart 25 compares the univariate cross-sectional elasticities of demand for MF3 with respect to the log of real GPE per capita (the thick solid line) and the univariate cross-sectional elasticities of demand for MF2 with respect to the log of real GPE per capita (the thin solid line). The MF3 univariate cross-sectional elasticities took a lower value than the MF2 univariate cross-sectional elasticities and the values of the lower bound of the confidence interval of the MF2 cross-sectional elasticities at the 5% level (the thin dashed line) in entire sample period. The major difference between MF2 and MF3 is that MF3 also covers the deposits at Japan Post Bank, agricultural cooperatives, and fishery cooperatives, which consist of individual deposits that are not sensitive to the business cycle. Hence we conjecture that the MF3 cross-sectional elasticities take a smaller value than the MF2 cross-sectional elasticities given the same control variables, and indeed the results support this conjecture.

Chart 26 compares the cross-sectional elasticities of demand for MF3 with respect to the log of real GPE per capita, also conditional on population density (the thick solid line), and the cross-sectional elasticities of demand for MF2 with respect to the log of real GPE per capita, also conditional on population density (the thin solid line). Again, the MF3 cross-sectional elasticities take a lower value than the MF2 cross-sectional elasticities, and their differences narrow after 2004, which is also consistent with the finding that the correlation coefficient between MF3/MF2 and the log real GPE per capita declines over time in **Chart 21**.

Chart 27 reports the results of the pooling regressions that attempt to reproduce the analysis for MF2 reported in **Chart 13**. As expected from the results of the cross-sectional analyses, the pooling elasticities of MF3 take smaller values than those of MF2 given the same independent variables.

D. Summary

When population density is added to the list of independent variables, the cross-sectional elasticities of demand for MF1 not only fall over time but also take values similar to the cross-sectional elasticities of demand for MF2, and lie within the bounds of the confidence interval for the MF2 cross-sectional elasticities at the 95% level, except for 1959. The MF3 cross-sectional elasticities take a smaller value than the MF2 cross-sectional elasticities given the same control variables as expected. In sum, the estimates obtained from MF2 are robust to the changes of the dependent variables into MF1 or MF3.

VIII. Summary and Implications

Fujiki and Mulligan (1996b) found that the estimates of elasticity for the log MF2 per capita deflated by prefectural CPI with respect to the log prefectural income per capita deflated by prefectural CPI conditional on the percentage share of primary industry took a value between 1.2 and 1.4 using data from fiscal 1955 to 1990. In this paper, we find that the estimates for elasticities of the log of real MF2 per capita deflated by GPE deflators with respect to the log of real GPE per capita deflated by GPE deflators conditional on population density take values similar to their results if we use the data in the 1980s. Our analysis using the sample period after the 1990s shows that the cross-sectional income elasticities decrease gradually over time, and reach a value of 0.93 in 2003. Our analysis using data from 2004 to 2009 shows that the cross-sectional income elasticities take a value from 0.6 to 0.7. The lower bound of the confidence interval for income elasticities evaluated at the 95% level are larger than zero in the entire sample. The results do not vary greatly with the addition of three independent variables other than population density: the percentage of gross prefectural product explained by primary industry, the percentage of GPE explained by the service industry, and the share of the population aged 65 years or older.

This paper tests the robustness of our benchmark results above from three perspectives. First, we check the robustness of our benchmark results against the measurement error of the data arising from the discrepancy between the prefectural deposit statistics and prefectural accounts statistics. We find that the different methods of estimation using the sample period of data before the 1990s could yield the income elasticities for money demand with respect to the log real GPE per capita that takes a value lower than one. Second, we check the robustness of our benchmark results against the replacement of independent variables from GPE to PPC. The cross-sectional elasticities of the demand for money with respect to the log of real PPC per capita appear to be stable over time compared with the cross-sectional elasticities of the demand for money with respect to the log of real GPE per capita conditional on the common explanatory variables. However, the bounds of the confidence interval for the GPE elasticities evaluated at the 95% level include the parameter estimates of PPC elasticities for most of the sample period. In this sense, the estimates for the two elasticities do not differ greatly from each other in size, and thus the results obtained from the log of real GPE per capita are robust to the use of the alternative scale variable. Third, we check the robustness of our benchmark results against the replacement of the dependent variable from MF2 to MF1 or MF3. Conditional on population density, the cross-sectional elasticities of demand for MF1 take similar values of the cross-sectional elasticities of demand for MF2. The MF3 cross-sectional elasticities take a smaller value than the MF2 cross-sectional elasticities given the same conditional variables. Therefore, the estimates obtained from MF2 are robust to the changes in the dependent variables into MF1 or MF3.

We conclude that the log of real MF2 per capita and the log of real GPE per capita conditional on the population density have a positive and gradually declining correlation by the early 2000s. The results after 2004 should not be taken literally due to the discontinuity in the prefectural deposit statistics. These results, taken at their face value based on our structural model (equation [11]), suggest that households and firms save the monetary inputs for their production activities over time: the additional real demand for M2 per capita for an additional unit of production activity increased by more than one unit by the 1990s, while it increased by less than one unit after 2000. Note that this interpretation requires us that our conditioning variables included in the vector Z do a good job of controlling the level of financial technology for each prefecture. Moreover, we should note that the estimates of income elasticities sometimes contain large standard errors.

Keeping these caveats in mind, our results imply that through the lens of our transaction theory of money, the regional real money balance per capita is unlikely to grow faster than the regional income growth rate after the mid-2000s. If we find that the prefectural real money balance per capita grows substantially faster than the growth rate of the prefecture, the demand for the real money balance should be motivated by other factors besides the transaction theory.

Unfortunately, as pointed out by McCallum and Nelson (2011), there is no consensus about the systematic use of information conveyed by the changes in monetary aggregates. Moreover, many readers might wonder about the usefulness of the traditional transaction theory of money in the aftermath of the global financial crises. However, the cross-validation of a structural model from various data sets is the only means of arriving at an empirically reliable policy recommendation. As stated by Lucas (2012), "You try to estimate a given parameter in as many ways as you can, consistent with the same theory. If you can reduce a 3 orders of magnitude discrepancy to 1 order of magnitude you are making progress.”

In this paper, we conducted the cross-validations of a model of the demand for money from time-series data and cross-sectional data. Such efforts are widely observed in other areas of economic research, for example, the test of the permanent income hypothesis or labor supply elasticity. The usefulness of the money demand should not be rejected on the grounds that we are in the midst of a financial crisis; rather, we should evaluate the usefulness through the accumulation of empirical studies. The latter avenue is the only way to arrive at a sound empirical foundation for policy recommendations, and there is no shortcut for this long and winding road.

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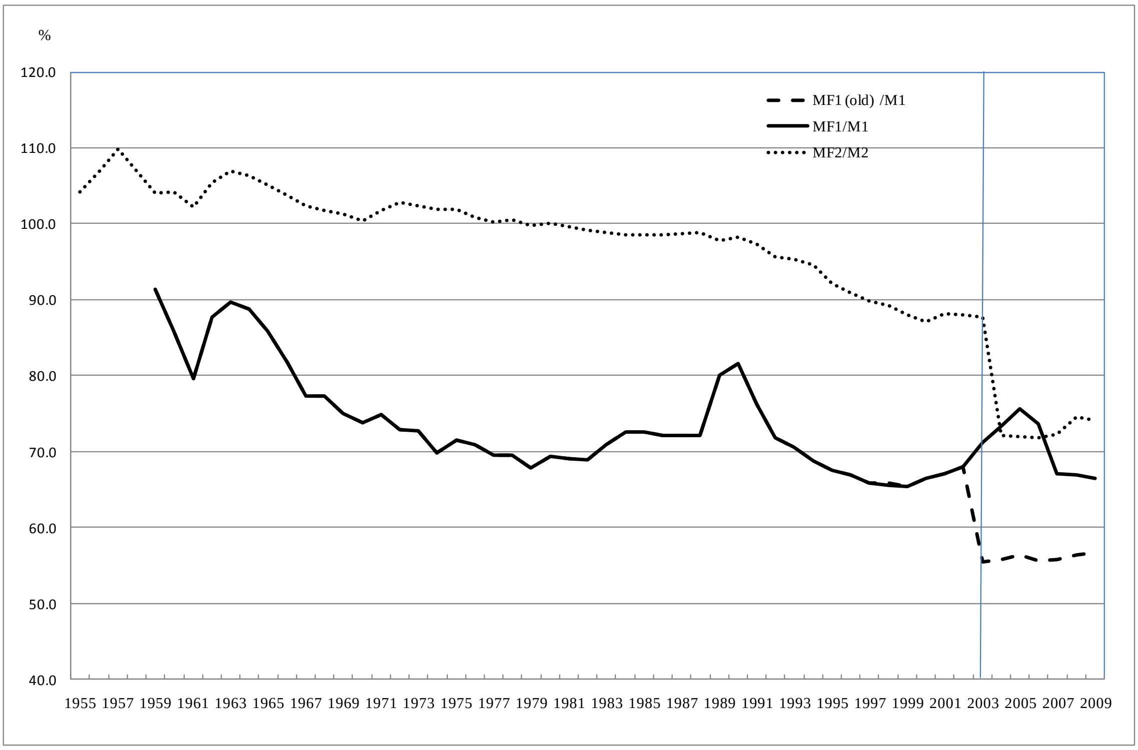
Chart 1: MF Statistics and the Money Stock



Notes: M1: M1, end of fiscal year outstanding (1955–2002: money supply statistics; 2003–2009: money stock statistics).

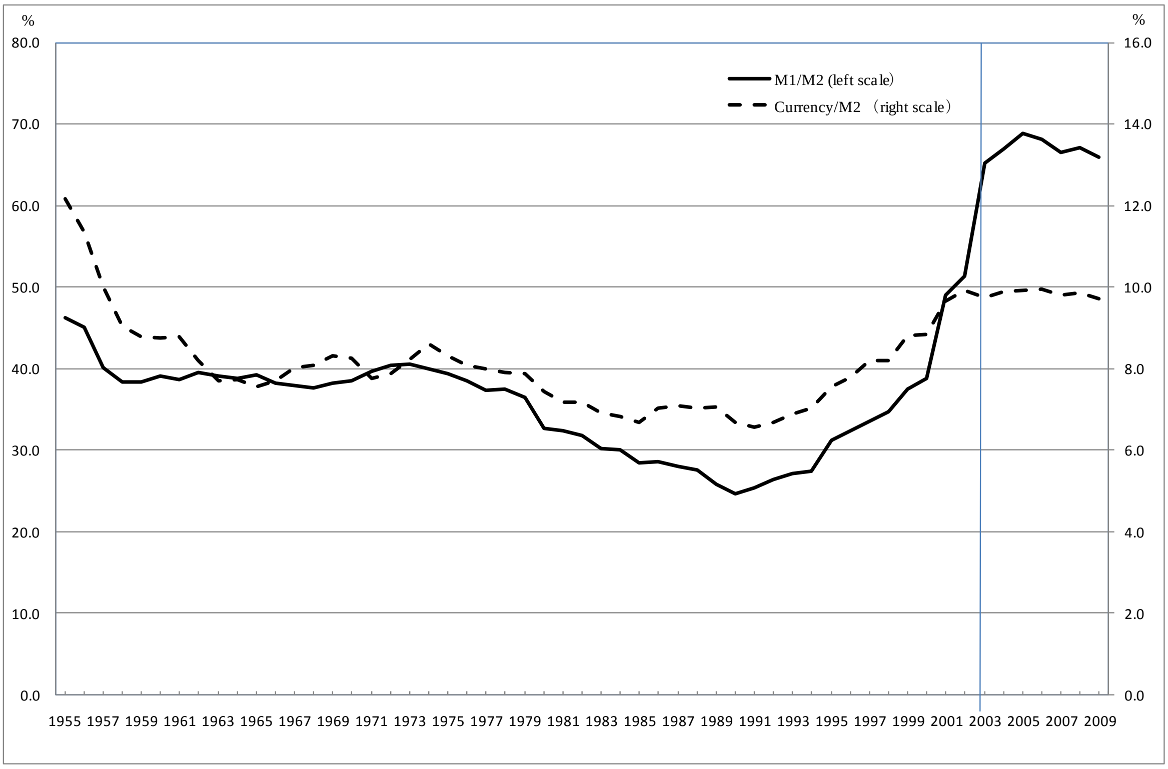
M2: end of fiscal year outstanding (1955–2002: M2+CDs in the money supply statistics; 2003–2009: M2 in the money stock statistics).

MF1: demand deposits, end of fiscal year outstanding (1955–2002: domestically licensed banks except for Japan Post Bank, including mutual banks after 1988; 2003–2009: domestically licensed banks and liquid deposits at Japan Post Bank, excluding Okinawa Prefecture).

MF1 (old): demand deposits, end of fiscal year outstanding (domestically licensed banks except for Japan Post Bank, including mutual banks after 1988, excluding Okinawa Prefecture).

MF2: demand deposits, time deposits, and foreign currency deposits at the fiscal year-end (1955–1987: domestically licensed banks (except for Japan Post Bank), mutual banks, *shinkin* banks, Shoko Chukin Bank; 1988–2002: domestically licensed banks (except for Japan Post Bank), *shinkin* banks, Shoko Chukin Bank; 2003–2009: domestically licensed banks excluding Okinawa Prefecture).

Chart 2: Trends in the Money Stock



Notes: Currency: currency in circulation, end of fiscal year outstanding (1955–2002: the money supply statistics; 2003–2009: money stock statistics).

M1: M1, end of fiscal year outstanding (1955–2002: money supply statistics; 2003–2009: money stock statistics).

M2: end of fiscal year outstanding (1955–2002: M2+CDs in the money supply statistics; 2003–2009: M2 in the money stock statistics).

Chart 3: Decomposition of M2+CDs in the Money Supply Statistics

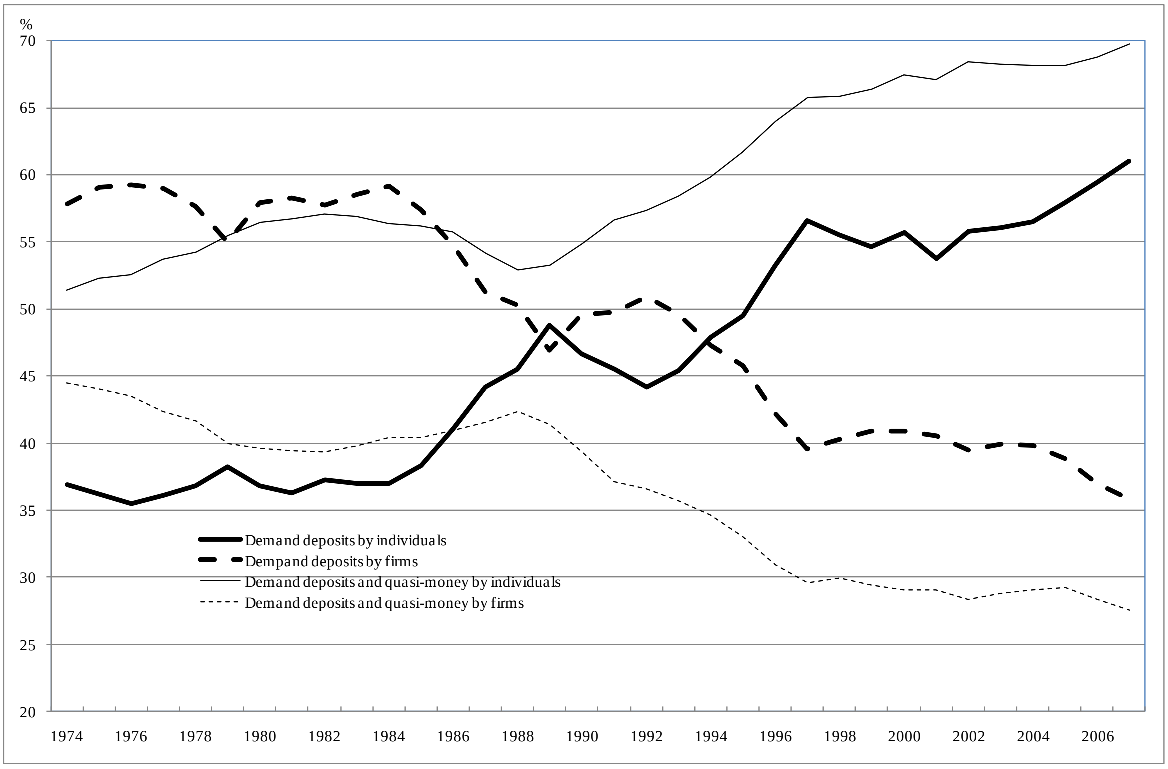
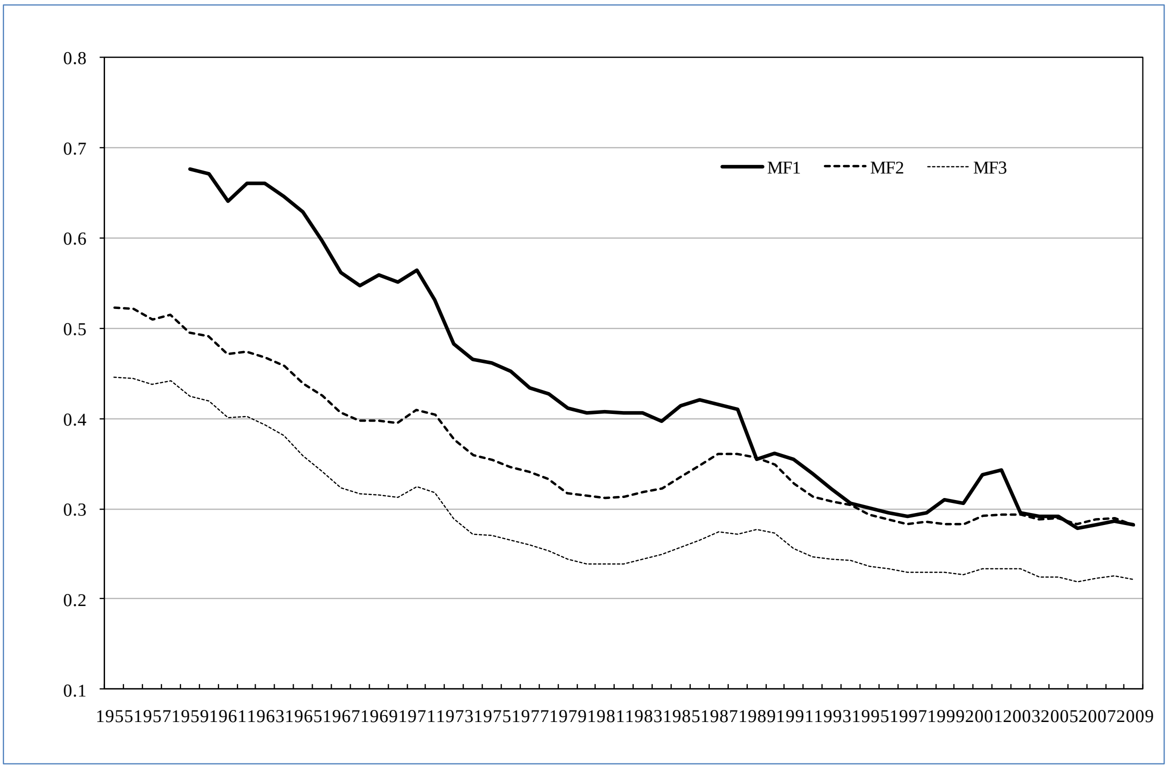


Chart 4: Dispersions of MF1, MF2, and MF3



Note: Dispersions are obtained in the following way. We first deflate MF1, MF2, and MF3 for each year by the GPE deflator normalized by the prefectural population, and then compute standard deviations of the log of the series in each year.

Chart 5: Dispersions of Real GPE per Capita and Real PPC per Capita

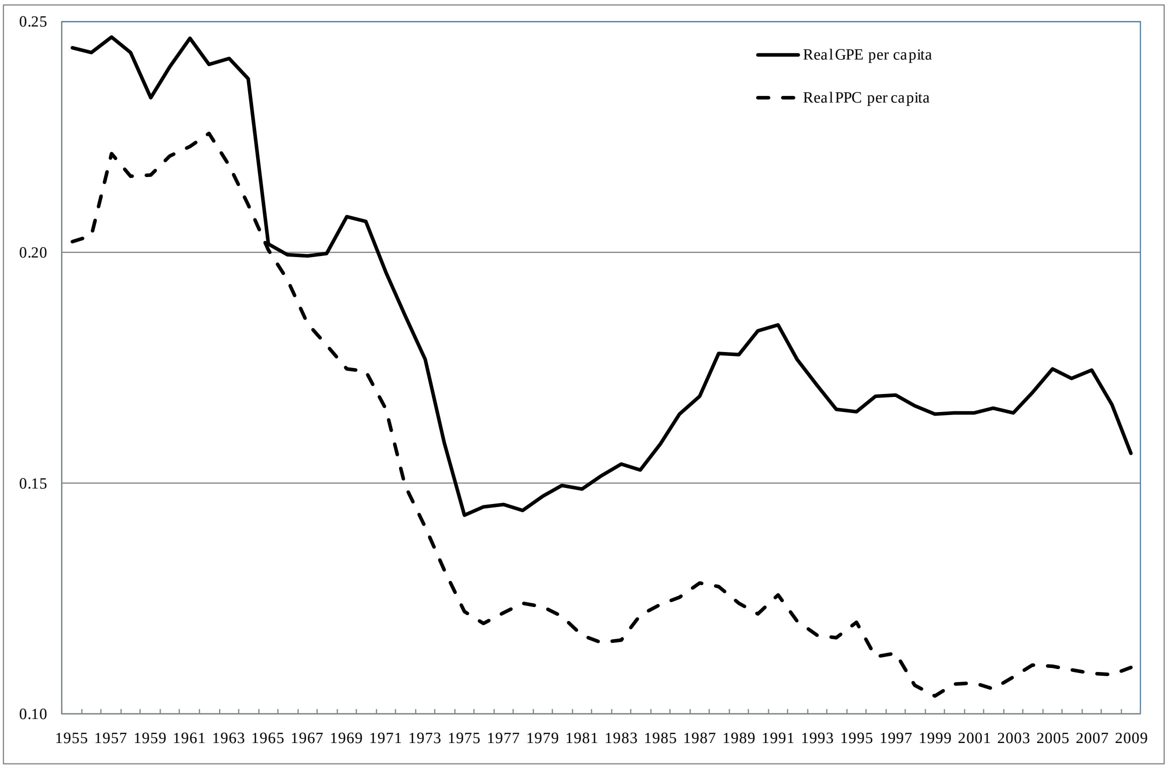


Chart 6: Log Real MF2 per Capita and Log Real GPE per Capita

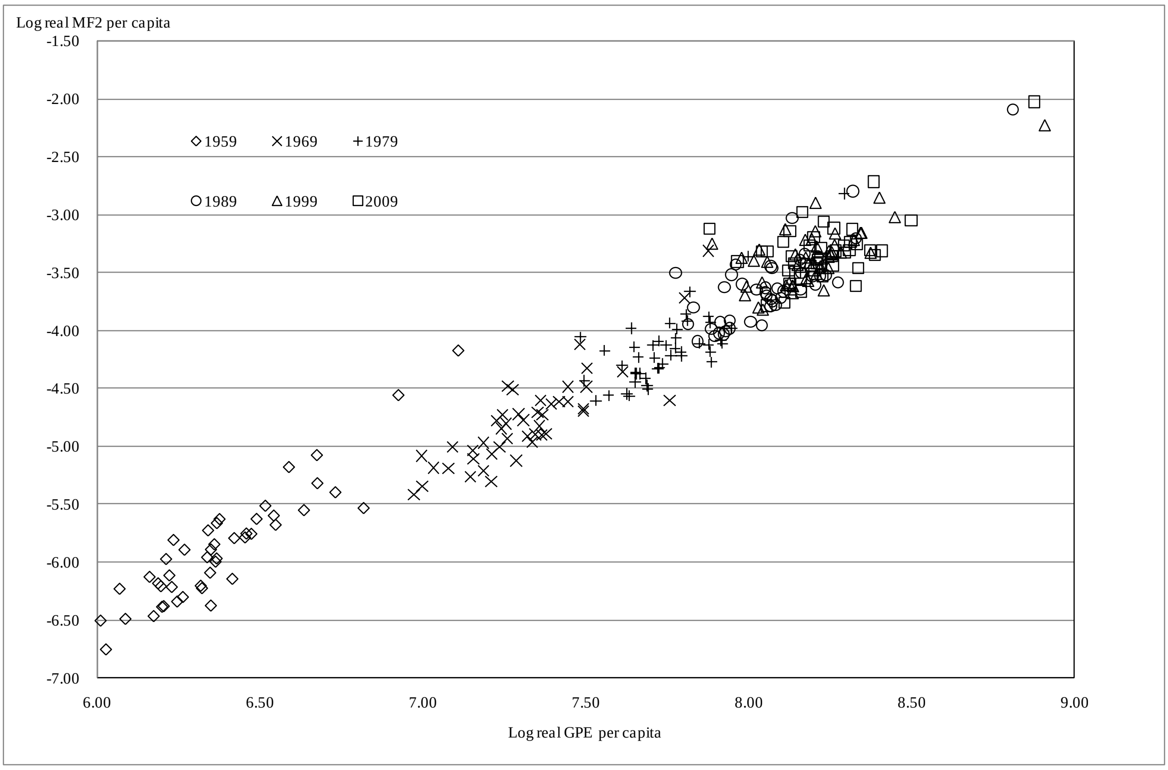
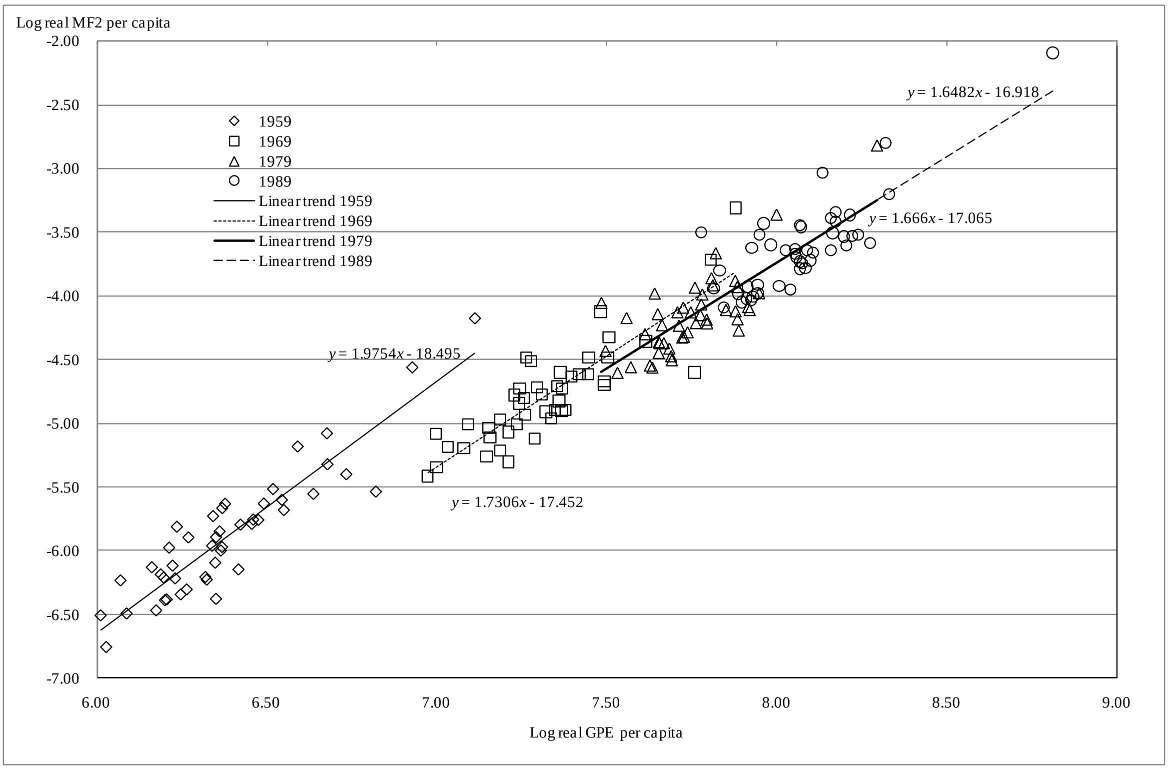


Chart 7: Log Real MF2 per Capita and Log Real GPE per Capita



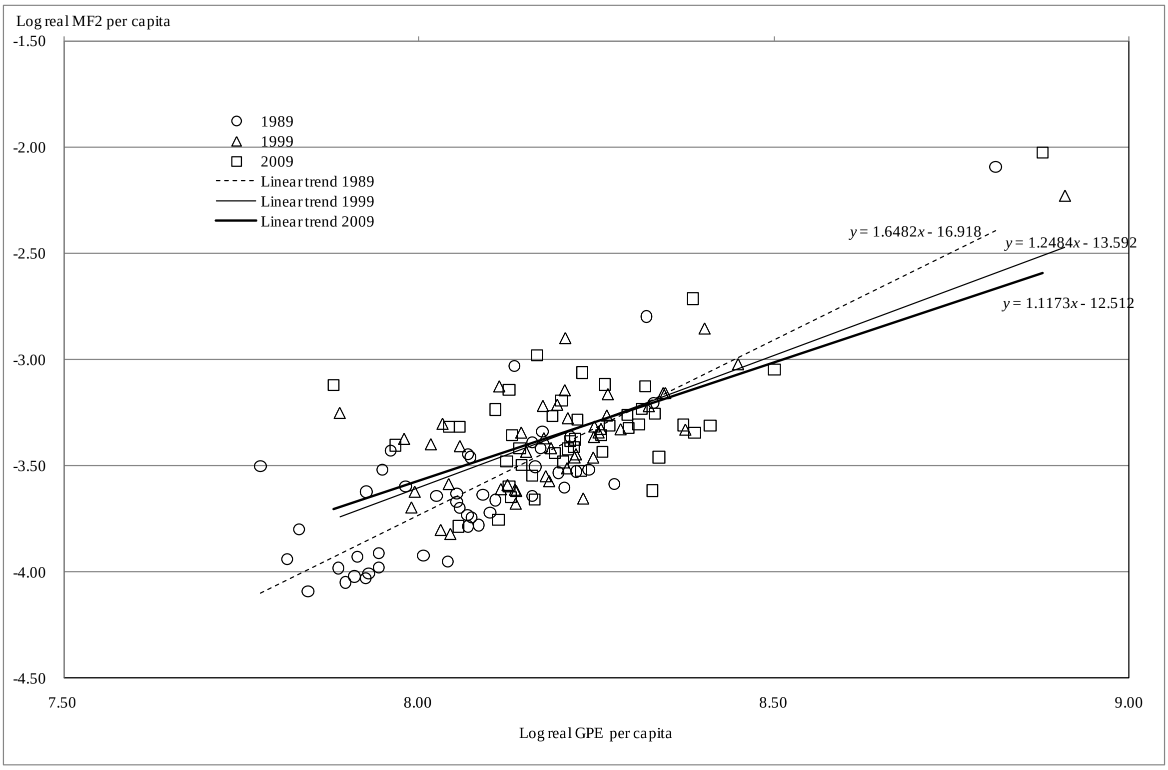


Chart 8: Japanese Demand for Money by Time-Series Estimation

(1) Test for Unit Root

		Lag length	Trend	Statistics	p-value	Sample period
Real M2 per capita	Level	1	Yes	-2.611	0.2749	1955-2009
Real GDP per capita	Level	1	Yes	-2.182	0.4999	1955-2009
Five year bond yield	Level	2	No	-0.524	0.8872	1955-2009

Note: Statistics come from the standard augmented Dickey-Fuller test. The null hypothesis is that the variable has a unit root. The p-value is the probability that the null hypothesis is rejected.

(2) Results of Time-Series Estimation

	Real GDP per capita		Five-year bond yield		Constant		*N*	*D.W.*	Statistics	p-value	Lag length
Level, 1955-2009	1.452***	(0.025)			2.696***	(0.154)	55	0.1588	-0.5250	0.8871	1
	1.323***	(0.047)	-0.0410***	(0.005)	2.135***	(0.258)	45	0.4097	-2.3200	0.1655	1
Difference, 1955-2009	0.885***	(0.158)			0.0265**	(0.008)	54	1.7990	-5.1480	0.0000	1
	0.851***	(0.162)	-0.0136*	(0.005)	0.0198**	(0.007)	44	1.3172	-5.0580	0.0000	1

Note: Estimation is done by OLS. The column labeled "Statistics" shows the test statistics for the augmented Dickey-Fuller test without a time trend. The null hypothesis is that the variable has a unit root. The column labeled "p-value" shows the probability that the null hypothesis is rejected. Numbers in parentheses are standard errors. *, **, and *** indicate that the parameter is statistically different from zero at 5%, 1%, and 0.1% if the standard errors follow the normal distribution.

(3) Results of Time-Series Estimation by Subsample Periods

	Real GDP per capita		Five-year bond yield		Constant		*N*	*D.W.*
Level up to 1989	1.335***	(0.019)			1.906***	(0.122)	35	0.5956
	1.307***	(0.037)	-0.0332***	(0.007)	1.973***	(0.207)	25	0.7317
Level after 1990	3.027***	(0.277)			11.56***	(1.548)	20	0.6595
	2.570***	(0.310)	-0.0231*	(0.010)	9.055***	(1.718)	20	0.7290
Difference up to 1989	0.910***	(0.250)			0.0291	(0.016)	34	1.9894
	1.003***	(0.234)	-0.0191**	(0.007)	0.0151	(0.013)	24	1.3849
Difference after 1990	-0.186	(0.303)			0.0304***	(0.005)	19	0.3898
	-0.301	(0.288)	0.0154	(0.008)	0.0364***	(0.006)	19	1.0403

Note: Estimation is done by OLS. Numbers in parentheses are standard errors. *, **, and *** indicate that the parameter is statistically different from zero at 5%, 1%, and 0.1% if the standard errors follow the normal distribution.

Chart 9: GPE Elasticity of MF2 (Cross-Sectional Univariate and Multiple Regressions)

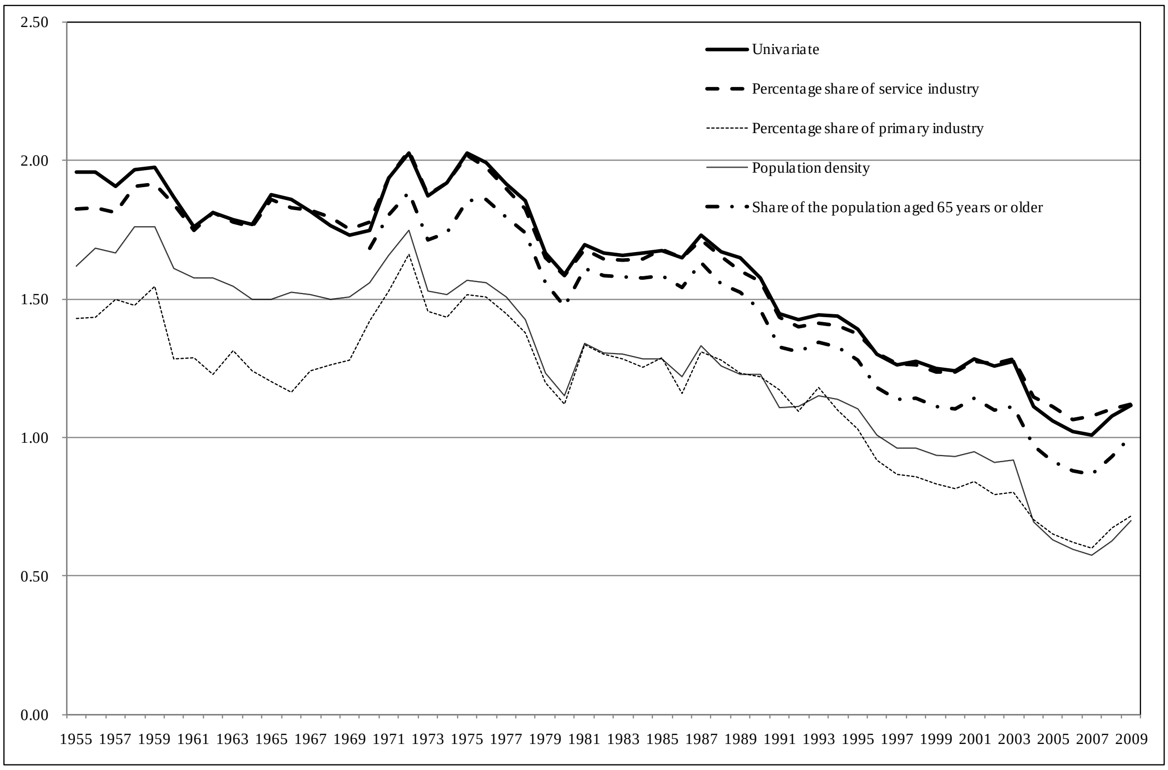


Chart 10: GPE Elasticity and Population Density Elasticity of MF2 (Benchmark)

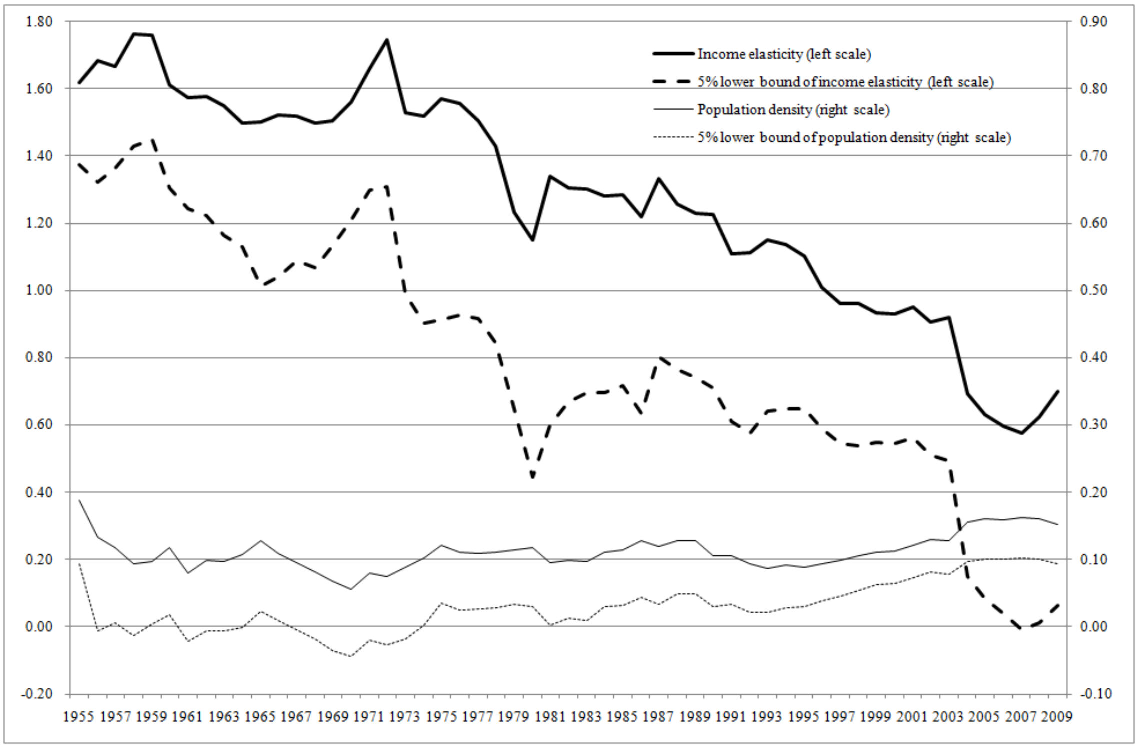
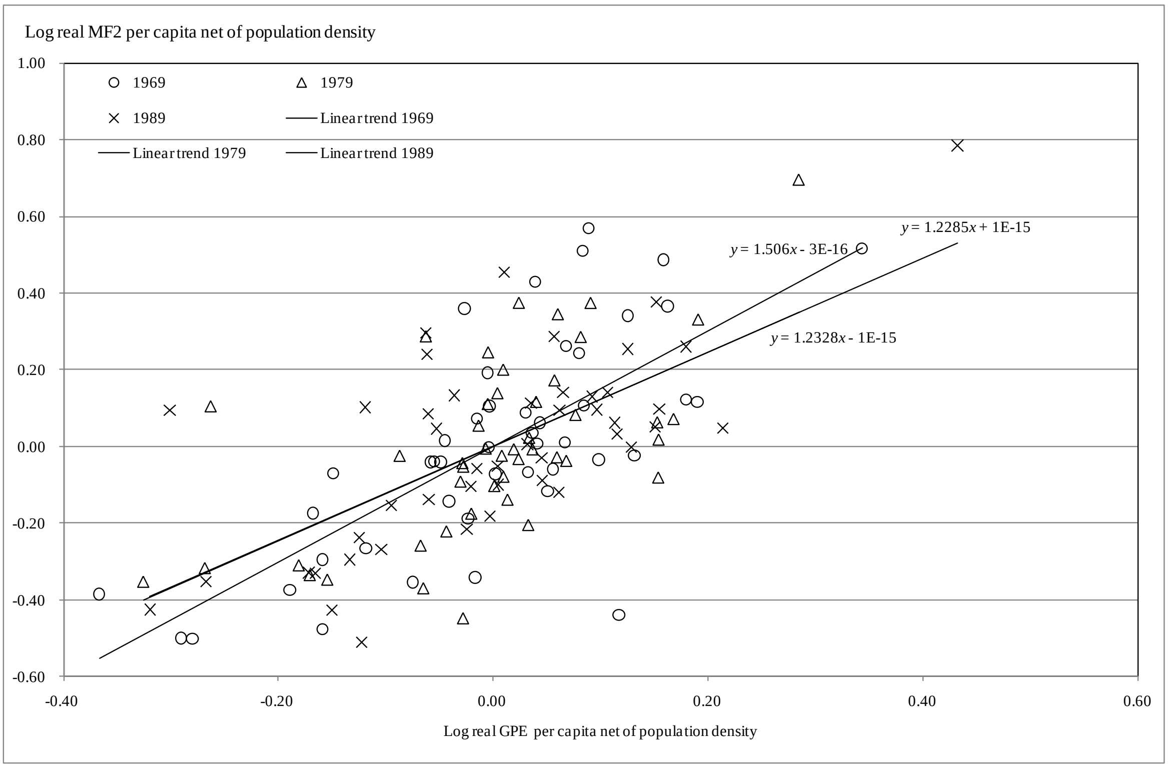


Chart 11: GPE Elasticity of MF2 Conditional on Population Density (Benchmark)



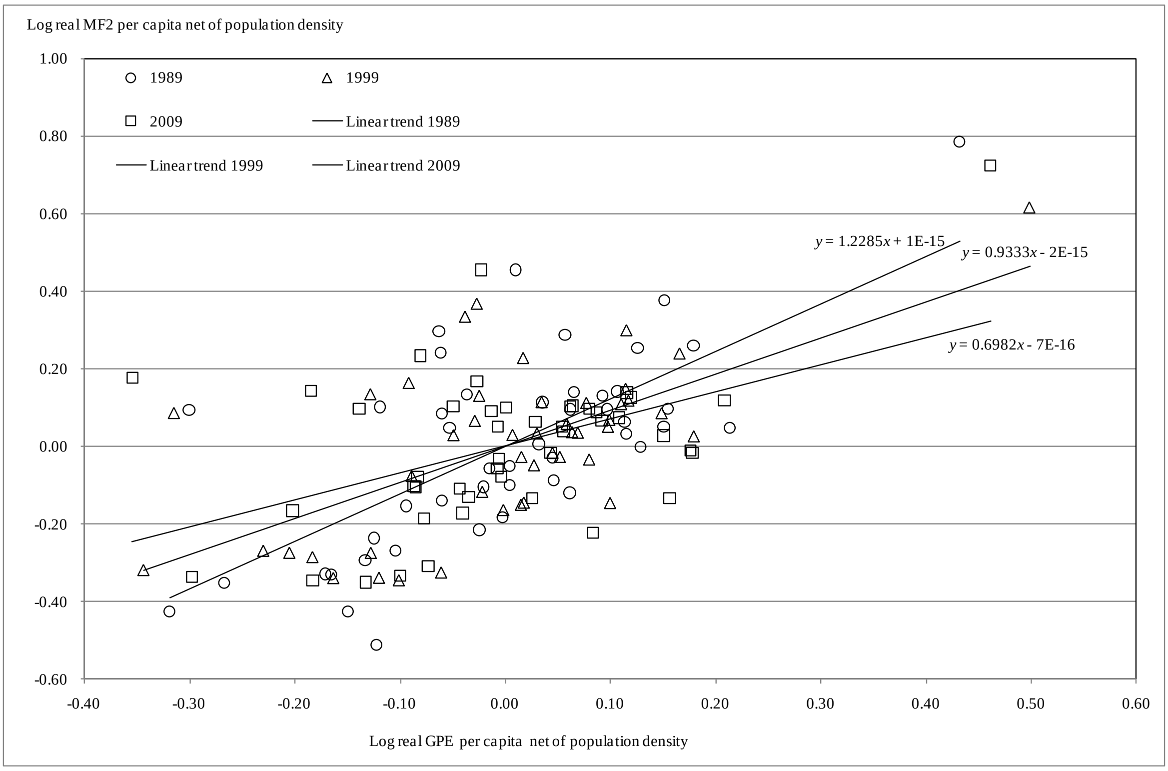


Chart 12: GPE Elasticity of MF2 Conditional on Several Variables

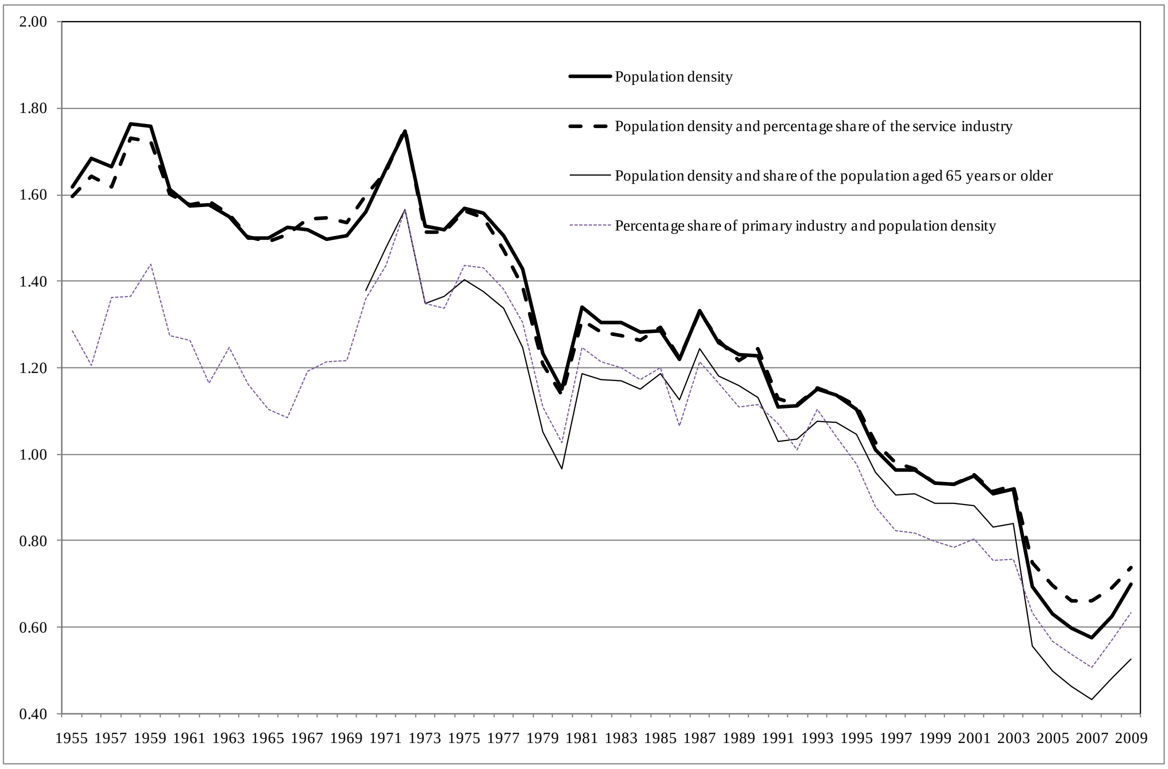


Chart 13: PE Elasticity of MF2: Pooling Estimates

	GPE		Percentage share of primary industry		Population density		Percentage share of the service industry		The share of the population aged 65 years or older		Observations
1955-2009	1.658***	(0.0359)									2,530
	1.203***	(0.0494)	-0.0264***	(0.00162)							2,530
	1.330***	(0.0328)			0.112***	(0.00531)					2,530
	1.633***	(0.0322)					0.0215***	(0.00171)			2,530
	1.062***	(0.0393)	-0.0202***	(0.00152)	0.0848***	(0.00534)					2,530
	1.145***	(0.0394)	-0.0281***	(0.00150)			0.0252***	(0.00167)			2,530
	1.330***	(0.0320)			0.105***	(0.00530)	0.0170***	(0.00165)			2,530
	1.033***	(0.0349)	-0.0224***	(0.00142)	0.0733***	(0.00492)	0.0213***	(0.00155)			2,530
1970-2009	1.395***	(0.0488)							-0.0229***	(0.00213)	1,840
	1.109***	(0.0596)	-0.0320***	(0.00235)					-0.0113***	(0.00193)	1,840
	1.374***	(0.0415)					0.0239***	(0.00219)	-0.0255***	(0.00208)	1,840
	1.115***	(0.0409)			0.138***	(0.00713)			0.0104***	(0.00252)	1,840
	0.985***	(0.0480)	-0.0210***	(0.00242)	0.110***	(0.00776)			0.0111***	(0.00243)	1,840
	1.016***	(0.0421)	-0.0391***	(0.00228)			0.0327***	(0.00208)	-0.0122***	(0.00184)	1,840
	1.133***	(0.0398)			0.124***	(0.00658)	0.0139***	(0.00201)	0.00532*	(0.00225)	1,840
	0.958***	(0.0411)	-0.0304***	(0.00243)	0.0707***	(0.00678)	0.0250***	(0.00203)	0.00240	(0.00213)	1,840
1955-2003	1.717***	(0.0365)									2,254
	1.266***	(0.0502)	-0.0244***	(0.00160)							2,254
	1.413***	(0.0338)			0.103***	(0.00581)					2,254
	1.691***	(0.0333)					0.0188***	(0.00180)			2,254
	1.143***	(0.0408)	-0.0189***	(0.00152)	0.0758***	(0.00582)					2,254
	1.202***	(0.0415)	-0.0261***	(0.00151)			0.0230***	(0.00175)			2,254
	1.406***	(0.0334)			0.0977***	(0.00579)	0.0154***	(0.00175)			2,254
	1.103***	(0.0371)	-0.0211***	(0.00144)	0.0662***	(0.00542)	0.0199***	(0.00165)			2,254
1970-2003	1.480***	(0.0504)							-0.0228***	(0.00236)	1,564
	1.192***	(0.0615)	-0.0285***	(0.00230)					-0.0116***	(0.00210)	1,564
	1.455***	(0.0443)					0.0205***	(0.00238)	-0.0252***	(0.00232)	1,564
	1.224***	(0.0436)			0.118***	(0.00758)			0.00512	(0.00268)	1,564
	1.087***	(0.0513)	-0.0198***	(0.00243)	0.0893***	(0.00828)			0.00609*	(0.00257)	1,564
	1.085***	(0.0455)	-0.0355***	(0.00227)			0.0303***	(0.00227)	-0.0124***	(0.00204)	1,564
	1.234***	(0.0431)			0.107***	(0.00710)	0.0128***	(0.00221)	0.000860	(0.00241)	1,564
	1.041***	(0.0447)	-0.0290***	(0.00244)	0.0536***	(0.00734)	0.0246***	(0.00222)	-0.00166	(0.00231)	1,564
2004-2009	1.065***	(0.158)									276
	0.658***	(0.186)	-0.104***	(0.0105)							276
	0.635***	(0.115)			0.158***	(0.0119)					276
	1.103***	(0.108)					0.0334***	(0.00533)			276
	0.571***	(0.140)	-0.0344*	(0.0163)	0.133***	(0.0182)					276
	0.632***	(0.102)	-0.124***	(0.00987)			0.0432***	(0.00514)			276
	0.698***	(0.0994)			0.143***	(0.0114)	0.0194***	(0.00480)			276
	0.591***	(0.101)	-0.0813***	(0.0135)	0.0718***	(0.0139)	0.0328***	(0.00504)			276
	0.925***	(0.162)							-0.0247***	(0.00436)	276
	0.659***	(0.187)	-0.108***	(0.0121)					0.00252	(0.00433)	276
	0.955***	(0.108)					0.0347***	(0.00535)	-0.0265***	(0.00420)	276
	0.647***	(0.106)			0.225***	(0.0140)			0.0340***	(0.00519)	276
	0.548***	(0.127)	-0.0543***	(0.0150)	0.196***	(0.0198)			0.0402***	(0.00512)	276
	0.635***	(0.103)	-0.133***	(0.0110)			0.0436***	(0.00510)	0.00643	(0.00431)	276
	0.684***	(0.0997)			0.203***	(0.0111)	0.0121**	(0.00460)	0.0276***	(0.00443)	276
	0.569***	(0.101)	-0.0861***	(0.0138)	0.133***	(0.0155)	0.0257***	(0.00498)	0.0304***	(0.00451)	276

Note: Numbers in parentheses are heteroskedasticity-robust standard errors. *, **, and *** indicate statistical significance at 5%, 1%, and 0.1 % level.

Chart 14: GPE Elasticity of MF2: Cross-Sectional Estimates Omitting Tokyo

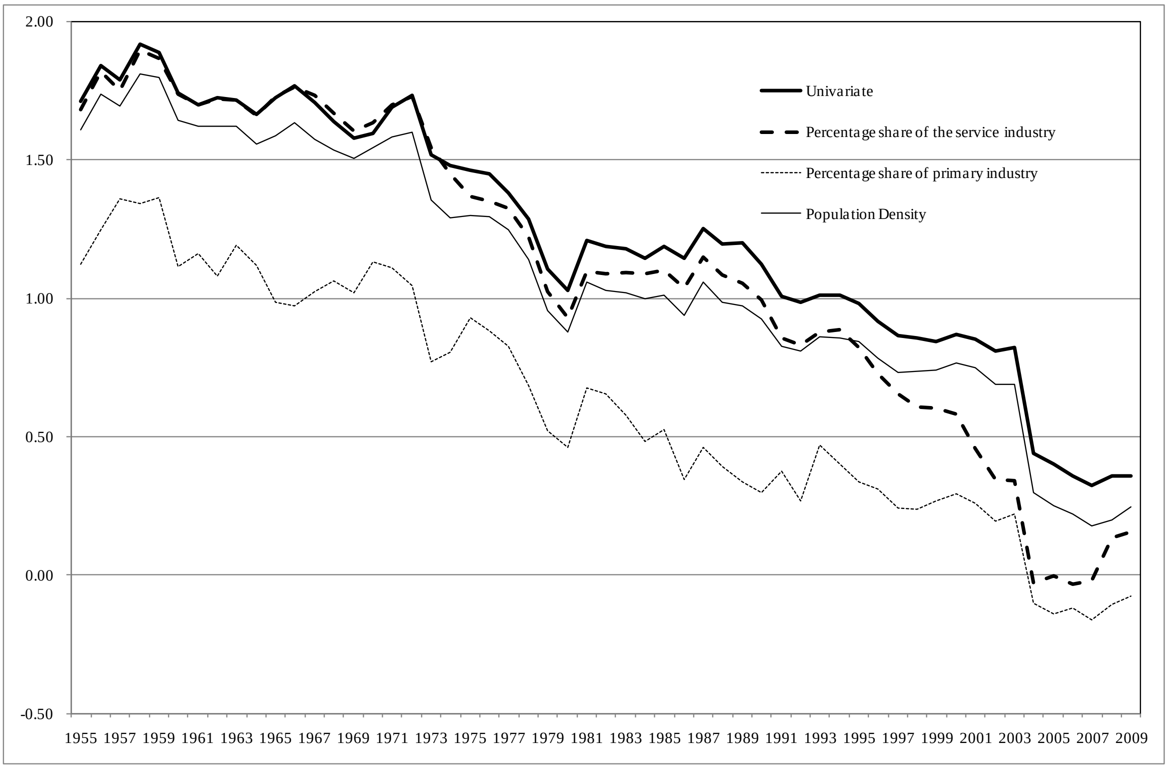


Chart 15: GPE Elasticity of MF2: Pooling Estimates with Fixed Effects

	GPE		Percentage share of primary industry		Population density		Percentage share of the service industry		The share of the population aged 65 years or older		Observations
1955-2009	0.856***	(0.105)									2,530
	0.573***	(0.0942)	-0.0166***	(0.00386)							2,530
	0.801***	(0.109)			-0.152	(0.110)					2,530
	0.858***	(0.104)					0.00349	(0.00594)			2,530
	0.557***	(0.0980)	-0.0159***	(0.00383)	-0.0776	(0.0838)					2,530
	0.576***	(0.0927)	-0.0166***	(0.00392)			0.00302	(0.00558)			2,530
	0.803***	(0.104)			-0.148	(0.115)	0.00170	(0.00645)			2,530
	0.560***	(0.0944)	-0.0159***	(0.00386)	-0.0730	(0.0879)	0.00216	(0.00599)			2,530
1970-2009	0.594***	(0.112)							0.0125	(0.00757)	1,840
	0.510***	(0.0998)	-0.0156*	(0.00607)					-0.00451	(0.00770)	1,840
	0.611***	(0.108)					0.00477	(0.00831)	0.0123	(0.00764)	1,840
	0.612***	(0.0979)			0.355	(0.197)			0.0304*	(0.0129)	1,840
	0.527***	(0.0851)	-0.0159**	(0.00579)	0.368*	(0.182)			0.0138	(0.0113)	1,840
	0.623***	(0.0952)			0.343	(0.210)	0.00335	(0.00789)	0.0296*	(0.0138)	1,840
	0.528***	(0.0962)	-0.0159*	(0.00623)			0.00585	(0.00712)	-0.00503	(0.00779)	1,840
	0.540***	(0.0843)	-0.0161**	(0.00593)	0.353	(0.187)	0.00439	(0.00648)	0.0126	(0.0114)	1,840
1955-2003	0.875***	(0.102)									2,254
	0.620***	(0.0915)	-0.0145***	(0.00396)							2,254
	0.817***	(0.104)			-0.160	(0.0990)					2,254
	0.875***	(0.101)					0.0000874	(0.00552)			2,254
	0.595***	(0.0961)	-0.0137**	(0.00395)	-0.108	(0.0772)					2,254
	0.620***	(0.0903)	-0.0145***	(0.00397)			-0.0000169	(0.00524)			2,254
	0.814***	(0.0985)			-0.165	(0.106)	-0.00216	(0.00607)			2,254
	0.593***	(0.0924)	-0.0137**	(0.00390)	-0.112	(0.0832)	-0.00153	(0.00567)			2,254
1970-2003	0.592***	(0.106)							0.00860	(0.00737)	1,564
	0.532***	(0.101)	-0.0129	(0.00659)					-0.00679	(0.00806)	1,564
	0.586***	(0.101)					-0.00199	(0.00792)	0.00852	(0.00720)	1,564
	0.601***	(0.0905)			0.457	(0.244)			0.0330	(0.0169)	1,564
	0.547***	(0.0901)	-0.0113	(0.00572)	0.380	(0.199)			0.0153	(0.0121)	1,564
	0.593***	(0.0849)			0.462	(0.246)	-0.00273	(0.00693)	0.0331	(0.0167)	1,564
	0.528***	(0.0971)	-0.0128	(0.00641)			-0.00148	(0.00679)	-0.00680	(0.00803)	1,564
	0.541***	(0.0861)	-0.0112*	(0.00551)	0.384	(0.202)	-0.00216	(0.00608)	0.0156	(0.0122)	1,564
2004-2009	0.276***	(0.0779)									276
	0.319***	(0.0710)	0.0373*	(0.0156)							276
	0.279***	(0.0771)			0.0381	(0.225)					276
	0.327***	(0.0773)					0.00734*	(0.00360)			276
	0.313***	(0.0711)	0.0398*	(0.0167)	-0.111	(0.223)					276
	0.358***	(0.0699)	0.0346*	(0.0157)			0.00613	(0.00350)			276
	0.330***	(0.0779)			0.0393	(0.222)	0.00734*	(0.00360)			276
	0.352***	(0.0715)	0.0369*	(0.0171)	-0.0989	(0.226)	0.00604	(0.00358)			276
	0.266**	(0.0757)							-0.00969	(0.00501)	276
	0.312***	(0.0665)	0.0459**	(0.0143)					-0.0147**	(0.00535)	276
	0.317***	(0.0755)					0.00757	(0.00382)	-0.0101*	(0.00495)	276
	0.277***	(0.0742)			0.176	(0.244)			-0.0120	(0.00646)	276
	0.314***	(0.0671)	0.0452**	(0.0150)	0.0435	(0.227)			-0.0152*	(0.00627)	276
	0.330***	(0.0755)			0.183	(0.240)	0.00764	(0.00381)	-0.0125	(0.00626)	276
	0.352***	(0.0666)	0.0432**	(0.0145)			0.00616	(0.00376)	-0.0148**	(0.00530)	276
	0.355***	(0.0682)	0.0423**	(0.0155)	0.0579	(0.229)	0.00622	(0.00383)	-0.0154*	(0.00613)	276

Note: Numbers in parentheses are heteroskedasticity-robust standard errors. *, **, and *** indicate statistical significance at 5%, 1%, and 0.1 % level.

Chart 16: GPE Elasticity of MF2: Pooling Estimates with Instrumental Variables

	GPE		Percentage share of primary industry		Population density		Percentage share of the service industry		Ratio of job offers to the number of job applicants		Observations	R^2	F-value
1963-2003	1.647***	(0.0440)									1,886	0.914	600.1
(OLS)	1.232***	(0.0575)	-0.0265***	(0.00189)							1,886	0.926	648.1
Independent var.	1.299***	(0.0395)			0.107***	(0.00611)					1,886	0.927	671.3
MX2	1.638***	(0.0401)					0.0182***	(0.00222)			1,886	0.917	638.6
	1.104***	(0.0465)	-0.0185***	(0.00187)	0.0776***	(0.00631)					1,886	0.932	740.4
	1.161***	(0.0455)	-0.0302***	(0.00179)			0.0263***	(0.00214)			1,886	0.932	706.0
	1.306***	(0.0395)			0.102***	(0.00610)	0.0141***	(0.00208)			1,886	0.929	670.3
	1.069***	(0.0416)	-0.0231***	(0.00176)	0.0633***	(0.00583)	0.0218***	(0.00200)			1,886	0.936	745.7
1963-2003	0.660***	(0.0227)									1,886		
(IV)	0.510***	(0.0230)	-0.0130***	(0.000783)							1,886		
Independent var.	0.653***	(0.0235)			-0.0265	(0.0231)					1,886		
MX2	0.651***	(0.0228)					-0.00544***	(0.00149)			1,886		
	0.524***	(0.0231)	-0.0142***	(0.000825)	0.102***	(0.0227)					1,886		
	0.501***	(0.0230)	-0.0130***	(0.000780)			-0.00533***	(0.00139)			1,886		
	0.642***	(0.0236)			-0.0315	(0.0230)	-0.00556***	(0.00149)			1,886		
	0.515***	(0.0231)	-0.0142***	(0.000823)	0.0971***	(0.0226)	-0.00496***	(0.00139)			1,886		
1963-2003									0.105***	(0.00823)	1,886	0.872	274.7
(IV first stage)			-0.0284***	(0.00102)					0.00642	(0.00501)	1,886	0.921	485.6
Independent var.					0.101***	(0.00521)			0.0728***	(0.00725)	1,886	0.915	390.7
GPE							0.0129***	(0.00367)	0.122***	(0.0106)	1,886	0.876	273.5
			-0.0195***	(0.00123)	0.0533***	(0.00696)			0.0201***	(0.00535)	1,886	0.928	559.7
			-0.0282***	(0.000970)			0.0109***	(0.00296)	0.0211***	(0.00629)	1,886	0.924	485.2
					0.0990***	(0.00468)	0.00447	(0.00240)	0.0790***	(0.00831)	1,886	0.915	381.0
			-0.0201***	(0.00117)	0.0489***	(0.00578)	0.00735**	(0.00240)	0.0289***	(0.00669)	1,886	0.929	523.1
2004-2009	1.065***	(0.158)									276	0.378	9.232
(OLS)	0.658***	(0.186)	-0.104***	(0.0105)							276	0.523	33.86
Independent var.	0.635***	(0.115)			0.158***	(0.0119)					276	0.614	33.10
MX2	1.103***	(0.108)					0.0334***	(0.00533)			276	0.461	17.11
	0.571***	(0.140)	-0.0344*	(0.0163)	0.133***	(0.0182)					276	0.623	32.03
	0.632***	(0.102)	-0.124***	(0.00987)			0.0432***	(0.00514)			276	0.659	44.78
	0.698***	(0.0994)			0.143***	(0.0114)	0.0194***	(0.00480)			276	0.639	44.42
	0.591***	(0.101)	-0.0813***	(0.0135)	0.0718***	(0.0139)	0.0328***	(0.00504)			276	0.679	40.13
2004-2009	0.276***	(0.0476)									276		
(IV)	0.319***	(0.0479)	0.0373***	(0.0104)							276		
Independent var.	0.279***	(0.0490)			0.0381	(0.136)					276		
MX2	0.327***	(0.0514)					0.00734*	(0.00299)			276		
	0.313***	(0.0485)	0.0398***	(0.0109)	-0.111	(0.139)					276		
	0.358***	(0.0512)	0.0346***	(0.0104)			0.00613*	(0.00295)			276		
	0.330***	(0.0527)			0.0393	(0.135)	0.00734*	(0.00299)			276		
	0.352***	(0.0519)	0.0369***	(0.0109)	-0.0989	(0.138)	0.00604*	(0.00295)			276		
2004-2009									0.422***	(0.0369)	276	0.415	22.55
(IV first stage)			-0.0245**	(0.00844)					0.346***	(0.0419)	276	0.432	21.18
Independent var.					0.0405**	(0.0134)			0.362***	(0.0277)	276	0.463	27.91
GPE							0.0115	(0.00696)	0.462***	(0.0524)	276	0.439	31.52
			0.00287	(0.0114)	0.0425*	(0.0180)			0.368***	(0.0444)	276	0.462	38.27
			-0.0235**	(0.00822)			0.0111	(0.00669)	0.388***	(0.0558)	276	0.455	34.58
					0.0343**	(0.0105)	0.00612	(0.00619)	0.393***	(0.0483)	276	0.468	33.68
			-0.00381	(0.00966)	0.0313*	(0.0130)	0.00654	(0.00614)	0.387***	(0.0544)	276	0.466	33.62

Note: Numbers in parentheses are heteroskedasticity-robust standard errors. *, **, and *** indicate statistical significance at 5%, 1%, and 0.1 % level.
Instrumental variable for GPE is the ratio of job offers to the number of job applicants and vairables except for GPE.

Chart 17: GPE Elasticity of MF2: Pooling Estimates with Fixed Effects and Lagged Dependent Variable

	Lag	GPE	Five-year bond yield	Percentage share of primary industry	Population density	Percentage share of the service industry	Share of the population aged 65 years or older	Observations	Long-run elasticity
1967-2003	0.761*** (0.0225)	0.241*** (0.0322)	-0.0116*** (0.000839)					1,702	1.008
A=B	0.754*** (0.0196)	0.233*** (0.0320)	-0.0120*** (0.000702)	-0.00169 (0.00125)				1,702	0.947
	0.759*** (0.0227)	0.240*** (0.0320)	-0.0117*** (0.000851)		0.0252 (0.0274)			1,702	0.996
	0.803*** (0.0212)	0.220*** (0.0259)	-0.0153*** (0.000746)			-0.00686*** (0.00136)		1,702	1.117
	0.743*** (0.0180)	0.225*** (0.0306)	-0.0123*** (0.000703)	-0.00280* (0.00133)	0.0680* (0.0295)			1,702	0.875
	0.799*** (0.0218)	0.217*** (0.0249)	-0.0153*** (0.000749)	-0.000648 (0.00110)		-0.00664*** (0.00118)		1,702	1.080
	0.800*** (0.0210)	0.219*** (0.0259)	-0.0154*** (0.000732)		0.0309 (0.0305)	-0.00691*** (0.00130)		1,702	1.095
	0.788*** (0.0205)	0.211*** (0.0239)	-0.0155*** (0.000717)	-0.00159 (0.00108)	0.0548 (0.0282)	-0.00644*** (0.00111)		1,702	0.995
1972-2003	0.800*** (0.0363)	0.252*** (0.0520)	-0.0153*** (0.000996)				-0.00722*** (0.00147)	1,426	1.260
A=B	0.791*** (0.0317)	0.241*** (0.0477)	-0.0161*** (0.000975)	-0.00331* (0.00145)			-0.00805*** (0.00144)	1,426	1.153
	0.809*** (0.0372)	0.252*** (0.0533)	-0.0157*** (0.000862)		-0.0392 (0.0336)		-0.00800*** (0.00138)	1,426	1.319
	0.817*** (0.0338)	0.245*** (0.0450)	-0.0161*** (0.00103)			-0.00481* (0.00190)	-0.00496** (0.00164)	1,426	1.339
	0.788*** (0.0311)	0.243*** (0.0490)	-0.0160*** (0.000889)	-0.00332* (0.00156)	0.00308 (0.0357)		-0.00791*** (0.00132)	1,426	1.146
	0.806*** (0.0319)	0.239*** (0.0432)	-0.0164*** (0.000980)	-0.00235 (0.00124)		-0.00362* (0.00159)	-0.00611*** (0.00152)	1,426	1.232
	0.812*** (0.0321)	0.248*** (0.0458)	-0.0159*** (0.000883)		0.0205 (0.0361)	-0.00512* (0.00200)	-0.00430** (0.00149)	1,426	1.319
	0.796*** (0.0303)	0.242*** (0.0435)	-0.0160*** (0.000884)	-0.00254 (0.00132)	0.0414 (0.0370)	-0.00414* (0.00163)	-0.00494*** (0.00140)	1,426	1.186
1967-2003	0.763*** (0.0223)	0.239*** (0.0319)	-0.0116*** (0.000833)					1,702	1.008
A=B=B=B	0.755*** (0.0196)	0.232*** (0.0317)	-0.0120*** (0.000700)	-0.00164 (0.00123)				1,702	0.947
	0.761*** (0.0224)	0.238*** (0.0315)	-0.0117*** (0.000845)		0.0273 (0.0266)			1,702	0.996
	0.803*** (0.0213)	0.218*** (0.0259)	-0.0152*** (0.000731)			-0.00663*** (0.00135)		1,702	1.107
	0.744*** (0.0179)	0.223*** (0.0300)	-0.0123*** (0.000705)	-0.00279* (0.00129)	0.0707* (0.0279)			1,702	0.871
	0.798*** (0.0220)	0.216*** (0.0250)	-0.0151*** (0.000736)	-0.000650 (0.00108)		-0.00633*** (0.00119)		1,702	1.069
	0.801*** (0.0209)	0.216*** (0.0257)	-0.0152*** (0.000723)		0.0326 (0.0296)	-0.00669*** (0.00128)		1,702	1.085
	0.788*** (0.0205)	0.210*** (0.0236)	-0.0153*** (0.000709)	-0.00163 (0.00103)	0.0583* (0.0266)	-0.00614*** (0.00110)		1,702	0.991
1972-2003	0.801*** (0.0364)	0.249*** (0.0521)	-0.0153*** (0.000981)				-0.00717*** (0.00148)	1,426	1.251
A=B=B=B	0.791*** (0.0318)	0.239*** (0.0478)	-0.0161*** (0.000960)	-0.00329* (0.00143)			-0.00798*** (0.00145)	1,426	1.144
	0.809*** (0.0370)	0.249*** (0.0529)	-0.0157*** (0.000861)		-0.0348 (0.0314)		-0.00789*** (0.00137)	1,426	1.304
	0.818*** (0.0343)	0.242*** (0.0454)	-0.0161*** (0.00102)			-0.00463* (0.00183)	-0.00500** (0.00159)	1,426	1.330
	0.789*** (0.0310)	0.240*** (0.0485)	-0.0160*** (0.000888)	-0.00335* (0.00154)	0.00799 (0.0343)		-0.00778*** (0.00133)	1,426	1.137
	0.806*** (0.0324)	0.237*** (0.0436)	-0.0164*** (0.000971)	-0.00239 (0.00124)		-0.00344* (0.00153)	-0.00614*** (0.00149)	1,426	1.222
	0.812*** (0.0320)	0.244*** (0.0456)	-0.0158*** (0.000881)		0.0227 (0.0346)	-0.00495* (0.00194)	-0.00431** (0.00145)	1,426	1.298
	0.796*** (0.0303)	0.239*** (0.0432)	-0.0160*** (0.000883)	-0.00261* (0.00132)	0.0446 (0.0361)	-0.00396* (0.00158)	-0.00494*** (0.00138)	1,426	1.172

Note: Numbers in parentheses are heteroskedasticity-robust standard errors. *, **, and *** indicate statistical significance at 5%, 1%, and 0.1 % level.
A=B shows estimates by Arellano and Bond (1991) and A=B=B=B shows estimates by Arellano and Bover (1995) and Blundell and Bond (1998).

Chart 18: GPE Elasticity and PPC Elasticity of MF2 (Cross-Sectional Univariate Regressions)

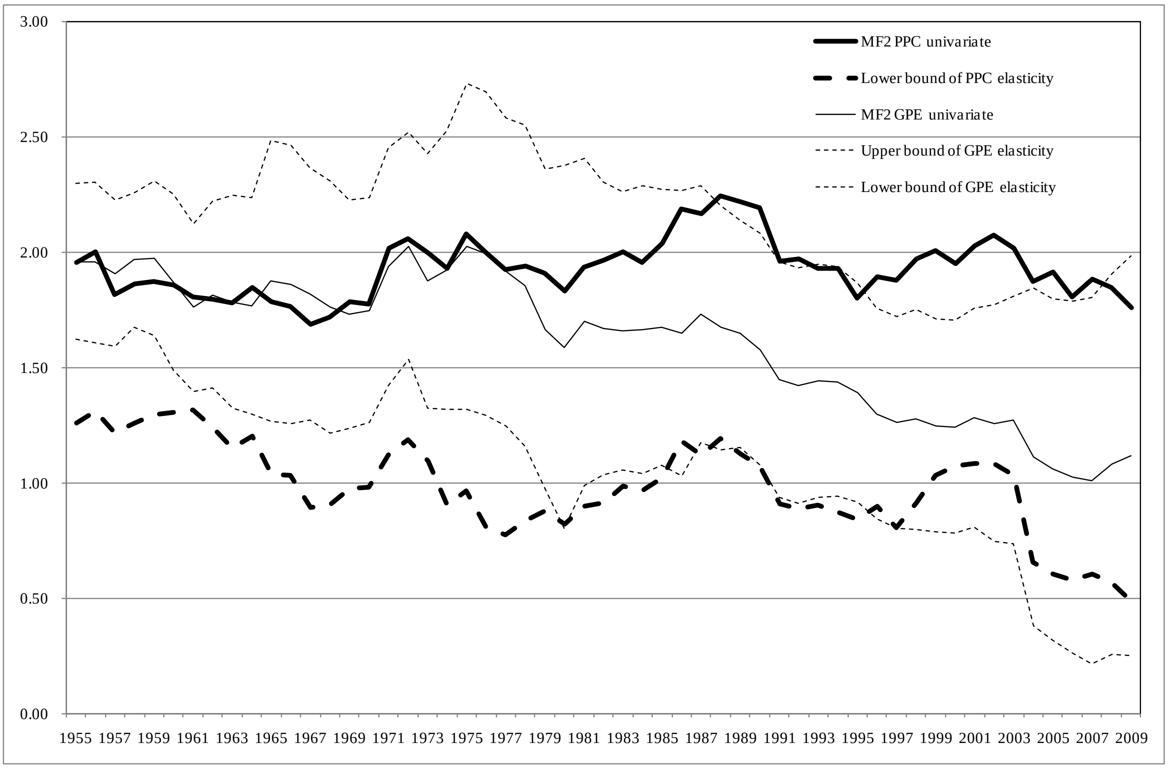


Chart 19: GPE Elasticity and PPC Elasticity of MF2 (Cross-Sectional Multiple Regressions)

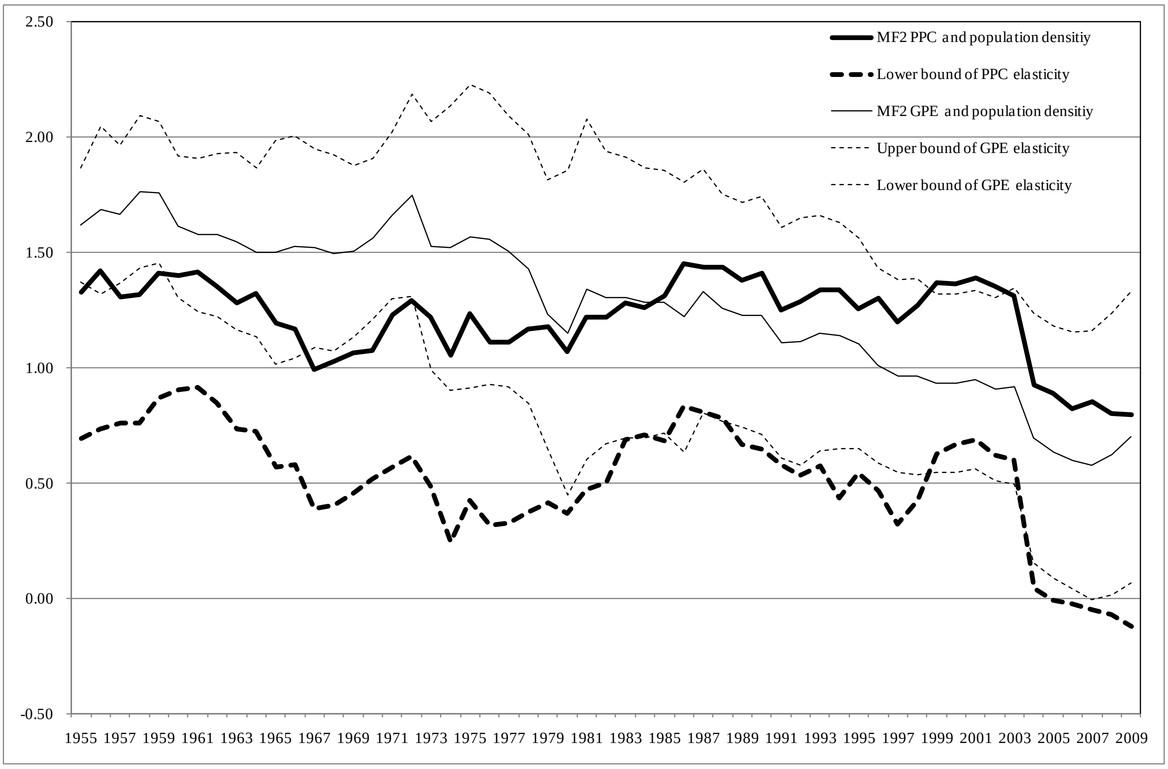


Chart 20: PPC Elasticity of MF2: Pooling Estimates

	PPC		Percentage share of primary industry		Population density		Percentage share of the service industry		The share of the population aged 65 years or older		Observations
1955-2009	1.898***	(0.0585)									2,530
	1.068***	(0.0679)	-0.0375***	(0.00168)							2,530
	1.334***	(0.0484)			0.139***	(0.00781)					2,530
	1.881***	(0.0485)					0.0295***	(0.00262)			2,530
	0.806***	(0.0498)	-0.0311***	(0.00175)	0.0998***	(0.00850)					2,530
	1.033***	(0.0530)	-0.0383***	(0.00156)			0.0314***	(0.00266)			2,530
	1.372***	(0.0456)			0.127***	(0.00719)	0.0224***	(0.00226)			2,530
	0.820***	(0.0448)	-0.0328***	(0.00159)	0.0829***	(0.00703)	0.0265***	(0.00226)			2,530
1970-2009	1.932***	(0.0922)							-0.00367	(0.00249)	1,840
	1.285***	(0.105)	-0.0418***	(0.00257)					0.00262	(0.00246)	1,840
	1.900***	(0.0738)					0.0259***	(0.00340)	-0.00672**	(0.00240)	1,840
	1.386***	(0.0619)			0.175***	(0.00914)			0.0318***	(0.00318)	1,840
	1.083***	(0.0747)	-0.0271***	(0.00286)	0.138***	(0.0111)			0.0284***	(0.00332)	1,840
	1.118***	(0.0694)	-0.0498***	(0.00243)			0.0367***	(0.00329)	-0.000523	(0.00238)	1,840
	1.412***	(0.0613)			0.162***	(0.00789)	0.0125***	(0.00284)	0.0277***	(0.00285)	1,840
	1.024***	(0.0638)	-0.0371***	(0.00262)	0.0968***	(0.00832)	0.0259***	(0.00287)	0.0185***	(0.00264)	1,840
1955-2003	1.901***	(0.0601)									2,254
	1.037***	(0.0687)	-0.0377***	(0.00166)							2,254
	1.354***	(0.0497)			0.140***	(0.00860)					2,254
	1.884***	(0.0500)					0.0300***	(0.00279)			2,254
	0.812***	(0.0514)	-0.0314***	(0.00177)	0.0943***	(0.00936)					2,254
	1.006***	(0.0542)	-0.0382***	(0.00156)			0.0316***	(0.00281)			2,254
	1.389***	(0.0468)			0.128***	(0.00790)	0.0233***	(0.00240)			2,254
	0.825***	(0.0462)	-0.0330***	(0.00162)	0.0777***	(0.00775)	0.0273***	(0.00242)			2,254
1970-2003	1.946***	(0.0970)							-0.00402	(0.00291)	1,564
	1.266***	(0.111)	-0.0411***	(0.00255)					0.00280	(0.00286)	1,564
	1.921***	(0.0786)					0.0258***	(0.00381)	-0.00700*	(0.00284)	1,564
	1.422***	(0.0659)			0.167***	(0.0101)			0.0292***	(0.00358)	1,564
	1.095***	(0.0809)	-0.0277***	(0.00295)	0.125***	(0.0124)			0.0254***	(0.00372)	1,564
	1.100***	(0.0738)	-0.0489***	(0.00246)			0.0377***	(0.00368)	-0.000258	(0.00278)	1,564
	1.449***	(0.0653)			0.154***	(0.00861)	0.0136***	(0.00320)	0.0251***	(0.00322)	1,564
	1.028***	(0.0688)	-0.0382***	(0.00271)	0.0816***	(0.00900)	0.0286***	(0.00326)	0.0153***	(0.00295)	1,564
2004-2009	1.847***	(0.255)									276
	1.073***	(0.306)	-0.0952***	(0.0110)							276
	0.847***	(0.177)			0.152***	(0.0163)					276
	1.829***	(0.195)					0.0259***	(0.00761)			276
	0.666**	(0.216)	-0.0460**	(0.0156)	0.122***	(0.0224)					276
	0.801***	(0.181)	-0.125***	(0.0110)			0.0394***	(0.00707)			276
	0.923***	(0.180)			0.138***	(0.0150)	0.0153*	(0.00679)			276
	0.638***	(0.177)	-0.0915***	(0.0121)	0.0672***	(0.0166)	0.0306***	(0.00678)			276
	1.786***	(0.296)							-0.00371	(0.00442)	276
	1.234***	(0.318)	-0.111***	(0.0114)					0.0174***	(0.00520)	276
	1.703***	(0.211)					0.0266***	(0.00763)	-0.00762*	(0.00375)	276
	1.114***	(0.168)			0.223***	(0.0193)			0.0450***	(0.00646)	276
	0.898***	(0.198)	-0.0624***	(0.0136)	0.192***	(0.0244)			0.0500***	(0.00678)	276
	0.962***	(0.186)	-0.141***	(0.0120)			0.0393***	(0.00685)	0.0174***	(0.00517)	276
	1.125***	(0.167)			0.214***	(0.0140)	0.00542	(0.00579)	0.0422***	(0.00494)	276
	0.840***	(0.165)	-0.0904***	(0.0124)	0.143***	(0.0160)	0.0206***	(0.00577)	0.0417***	(0.00530)	276

Note: Numbers in parentheses are heteroskedasticity-robust standard errors. *, **, and *** indicate statistical significance at 5%, 1%, and 0.1 % level.

Chart 21: Correlation between MF2/MF1, MF3/MF2, and Log Real GPE per Capita

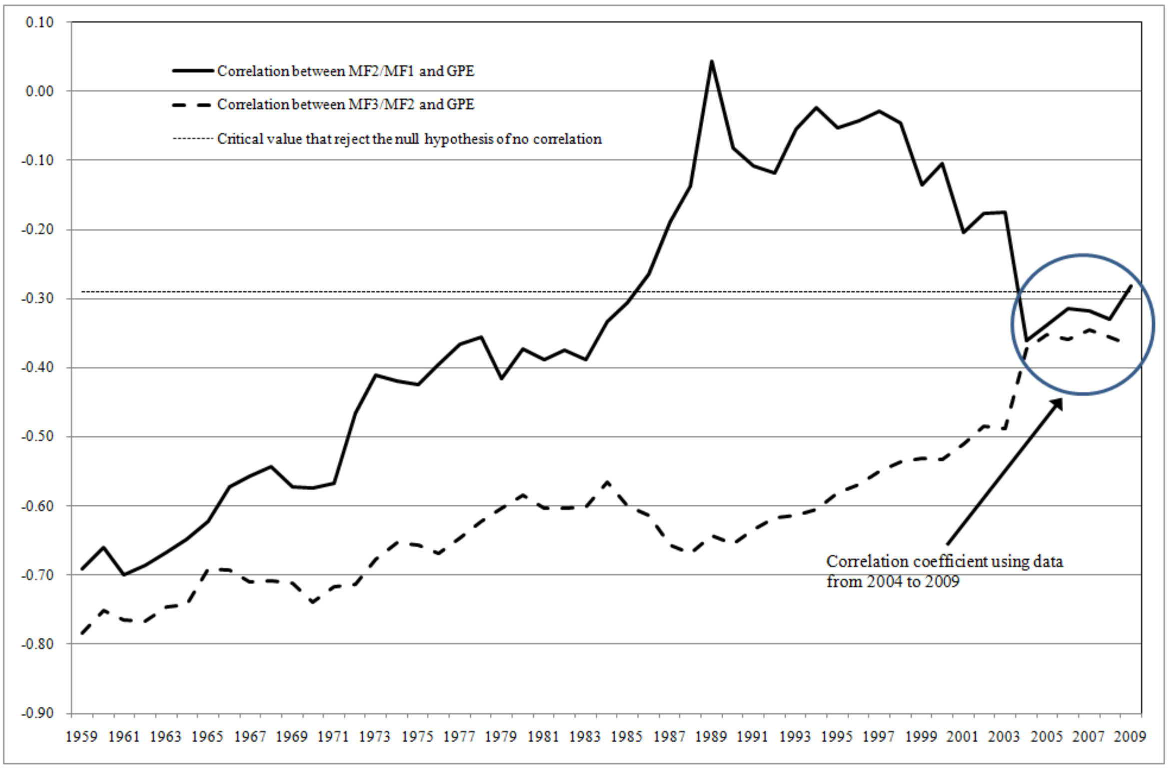


Chart 22: GPE Elasticity of MF1 and MF2 (Cross-Sectional Univariate Regressions)

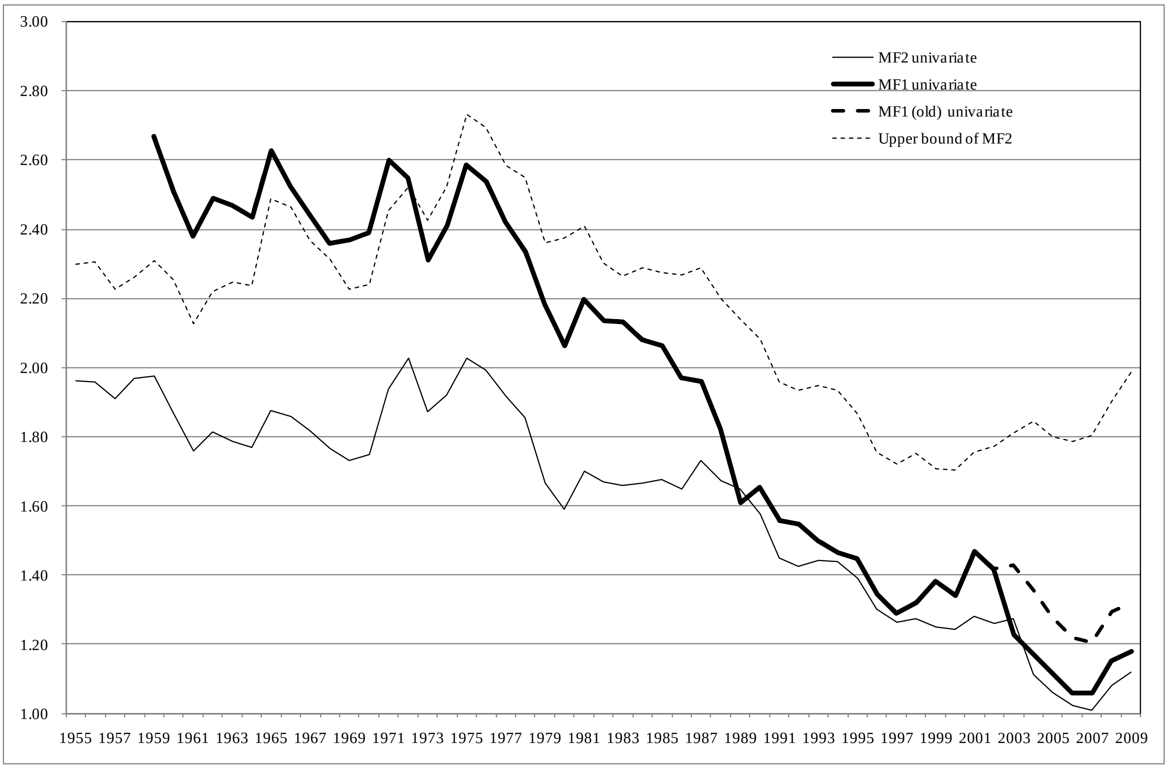


Chart 23: GPE Elasticity of MF1 and MF2 (Cross-Sectional Multiple Regressions)

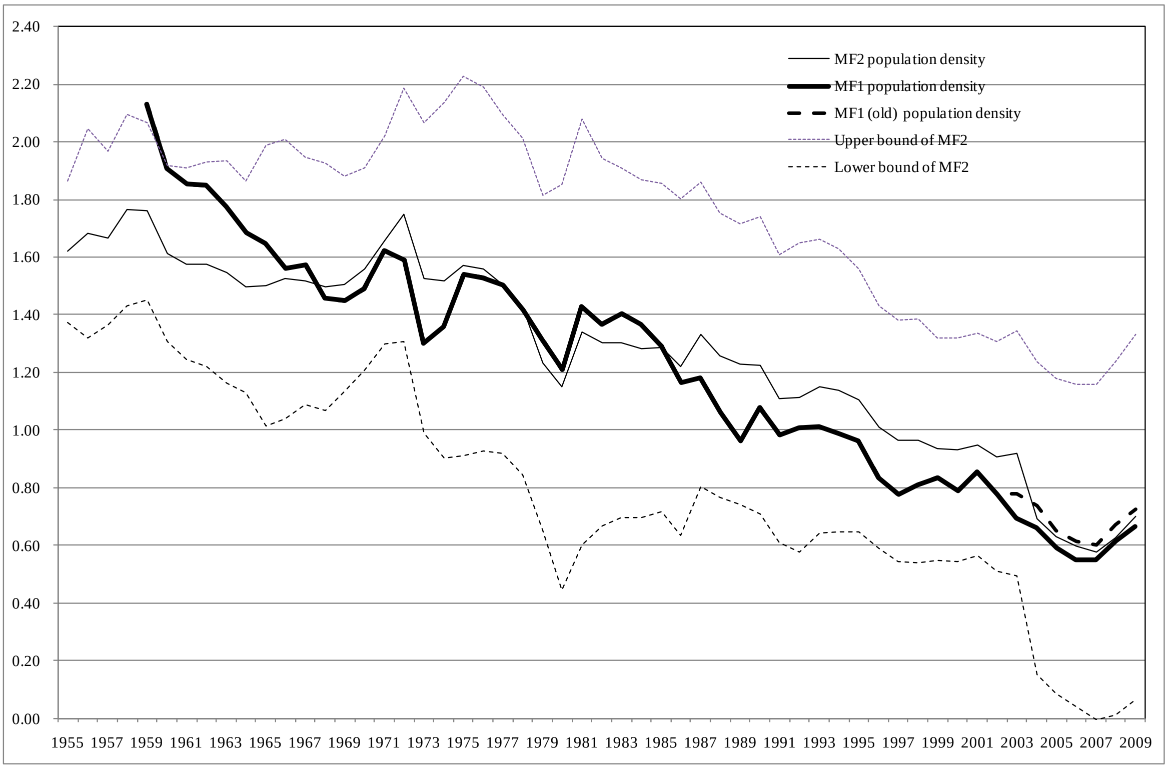


Chart 24: GPE Elasticity of MF1: Pooling Estimates

	GPE		Percentage share of primary industry		Population density		Percentage share of the service industry		The share of the population aged 65 years or older		Observations
1959-2009	1.996***	(0.0594)									2,346
	1.346***	(0.0749)	-0.0405***	(0.00224)							2,346
	1.339***	(0.0449)			0.214***	(0.00685)					2,346
	1.976***	(0.0519)					0.0427***	(0.00287)			2,346
	1.050***	(0.0508)	-0.0247***	(0.00201)	0.179***	(0.00733)					2,346
	1.240***	(0.0526)	-0.0456***	(0.00211)			0.0514***	(0.00261)			2,346
	1.364***	(0.0442)			0.201***	(0.00650)	0.0332***	(0.00245)			2,346
	1.007***	(0.0417)	-0.0311***	(0.00195)	0.154***	(0.00630)	0.0414***	(0.00220)			2,346
1970-2009	1.530***	(0.0722)							-0.0440***	(0.00228)	1,840
	1.234***	(0.0823)	-0.0331***	(0.00272)					-0.0320***	(0.00216)	1,840
	1.483***	(0.0539)					0.0529***	(0.00299)	-0.0497***	(0.00221)	1,840
	1.059***	(0.0508)			0.233***	(0.0104)			0.0120***	(0.00334)	1,840
	0.989***	(0.0578)	-0.0113***	(0.00257)	0.218***	(0.0111)			0.0125***	(0.00330)	1,840
	1.106***	(0.0454)			0.194***	(0.00776)	0.0373***	(0.00252)	-0.00145	(0.00244)	1,840
	1.053***	(0.0460)	-0.0470***	(0.00256)			0.0635***	(0.00276)	-0.0338***	(0.00193)	1,840
	0.937***	(0.0436)	-0.0293***	(0.00252)	0.142***	(0.00736)	0.0480***	(0.00246)	-0.00426	(0.00225)	1,840
1959-1988	2.387***	(0.0755)									1,334
	1.652***	(0.115)	-0.0329***	(0.00270)							1,334
	1.639***	(0.0595)			0.240***	(0.0111)					1,334
	2.367***	(0.0671)					0.0331***	(0.00410)			1,334
	1.380***	(0.0771)	-0.0159***	(0.00256)	0.210***	(0.0130)					1,334
	1.539***	(0.0954)	-0.0368***	(0.00258)			0.0419***	(0.00408)			1,334
	1.625***	(0.0590)			0.239***	(0.0103)	0.0316***	(0.00314)			1,334
	1.294***	(0.0695)	-0.0202***	(0.00237)	0.199***	(0.0111)	0.0366***	(0.00317)			1,334
1970-1988	1.954***	(0.109)							-0.0729***	(0.00477)	828
	1.667***	(0.147)	-0.0198***	(0.00346)					-0.0607***	(0.00462)	828
	1.860***	(0.0810)					0.0556***	(0.00470)	-0.0875***	(0.00510)	828
	1.416***	(0.0860)			0.212***	(0.0146)			-0.0197***	(0.00558)	828
	1.419***	(0.109)	0.000339	(0.00378)	0.213***	(0.0177)			-0.0197***	(0.00546)	828
	1.392***	(0.0747)			0.190***	(0.0110)	0.0475***	(0.00387)	-0.0377***	(0.00427)	828
	1.374***	(0.0964)	-0.0323***	(0.00287)			0.0666***	(0.00472)	-0.0705***	(0.00460)	828
	1.245***	(0.0878)	-0.0148***	(0.00308)	0.159***	(0.0122)	0.0538***	(0.00384)	-0.0380***	(0.00420)	828
1989-2003	1.472***	(0.101)									736
	1.213***	(0.140)	-0.0372***	(0.00667)							736
	0.900***	(0.0774)			0.185***	(0.00813)					736
	1.433***	(0.0546)					0.0553***	(0.00318)			736
	1.017***	(0.0912)	0.0290***	(0.00655)	0.213***	(0.00971)					736
	0.918***	(0.0642)	-0.0725***	(0.00531)			0.0701***	(0.00309)			736
	0.957***	(0.0526)			0.157***	(0.00716)	0.0413***	(0.00277)			736
	0.890***	(0.0607)	-0.0187**	(0.00591)	0.136***	(0.00773)	0.0470***	(0.00303)			736
1989-2003	1.275***	(0.104)							-0.0340***	(0.00268)	736
	1.237***	(0.132)	-0.00740	(0.00683)					-0.0317***	(0.00291)	736
	1.220***	(0.0521)					0.0573***	(0.00309)	-0.0367***	(0.00245)	736
	0.887***	(0.0731)			0.221***	(0.0129)			0.0171***	(0.00399)	736
	0.987***	(0.0882)	0.0240***	(0.00620)	0.235***	(0.0131)			0.0128***	(0.00356)	736
	0.956***	(0.0519)			0.159***	(0.00798)	0.0410***	(0.00272)	0.000936	(0.00256)	736
	0.947***	(0.0597)	-0.0511***	(0.00547)			0.0669***	(0.00307)	-0.0211***	(0.00231)	736
	0.886***	(0.0600)	-0.0191**	(0.00584)	0.140***	(0.00950)	0.0466***	(0.00307)	0.00223	(0.00245)	736
2004-2009	1.120***	(0.165)									276
	0.710***	(0.195)	-0.105***	(0.0101)							276
	0.603***	(0.108)			0.191***	(0.0101)					276
	1.170***	(0.0980)					0.0436***	(0.00461)			276
	0.589***	(0.129)	-0.00741	(0.0134)	0.185***	(0.0154)					276
	0.678***	(0.0894)	-0.129***	(0.00789)			0.0539***	(0.00439)			276
	0.692***	(0.0815)			0.170***	(0.00878)	0.0271***	(0.00361)			276
	0.612***	(0.0840)	-0.0604***	(0.00998)	0.116***	(0.0103)	0.0371***	(0.00408)			276
2004-2009	0.894***	(0.166)							-0.0400***	(0.00407)	276
	0.701***	(0.191)	-0.0781***	(0.0105)					-0.0203***	(0.00376)	276
	0.933***	(0.0896)					0.0458***	(0.00454)	-0.0425***	(0.00372)	276
	0.610***	(0.102)			0.229***	(0.0165)			0.0198***	(0.00553)	276
	0.577***	(0.122)	-0.0183	(0.0122)	0.220***	(0.0199)			0.0219***	(0.00532)	276
	0.688***	(0.0814)			0.183***	(0.0100)	0.0254***	(0.00366)	0.00639	(0.00375)	276
	0.671***	(0.0866)	-0.108***	(0.00801)			0.0530***	(0.00445)	-0.0156***	(0.00339)	276
	0.606***	(0.0841)	-0.0617***	(0.0100)	0.133***	(0.0133)	0.0351***	(0.00424)	0.00843*	(0.00347)	276

Note: Numbers in parentheses are heteroskedasticity-robust standard errors. *, **, and *** indicate statistical significance at 5%, 1%, and 0.1 % level.

Chart 25: GPE Elasticity of MF3 and MF2 (Cross-Sectional Univariate Regressions)

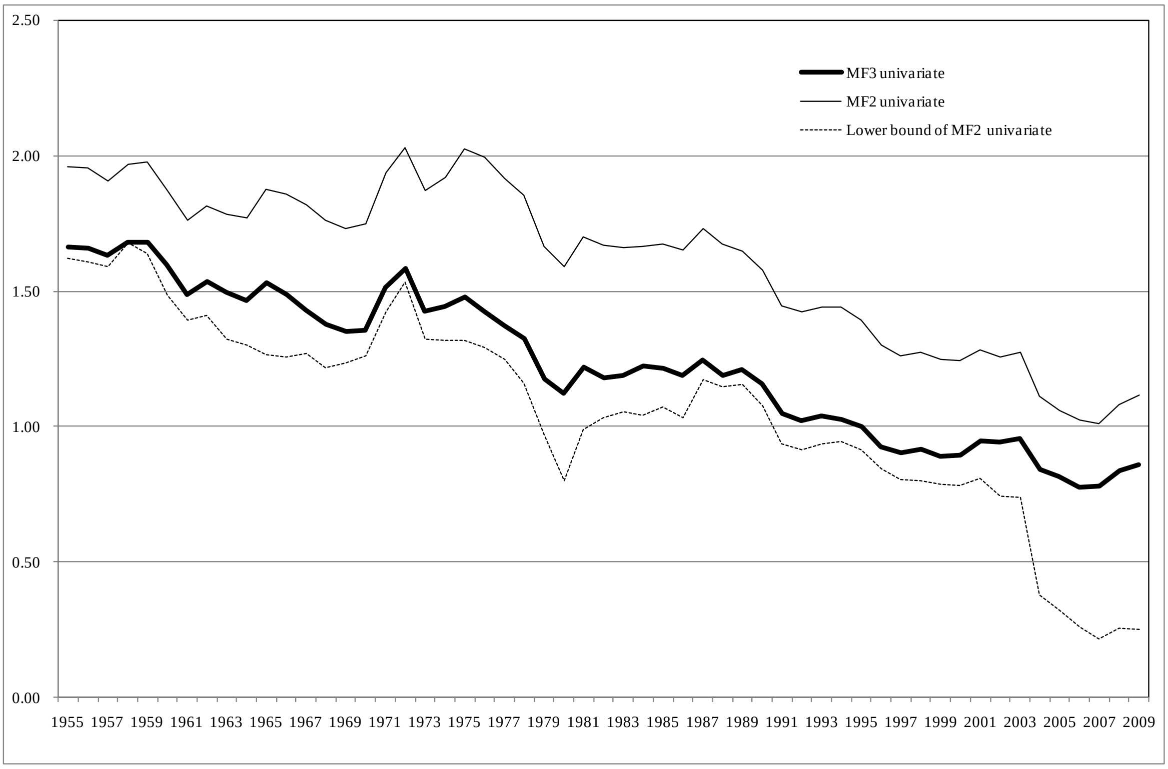


Chart 26: GPE Elasticity of MF3 and MF2 (Cross-Sectional Multiple Regressions)

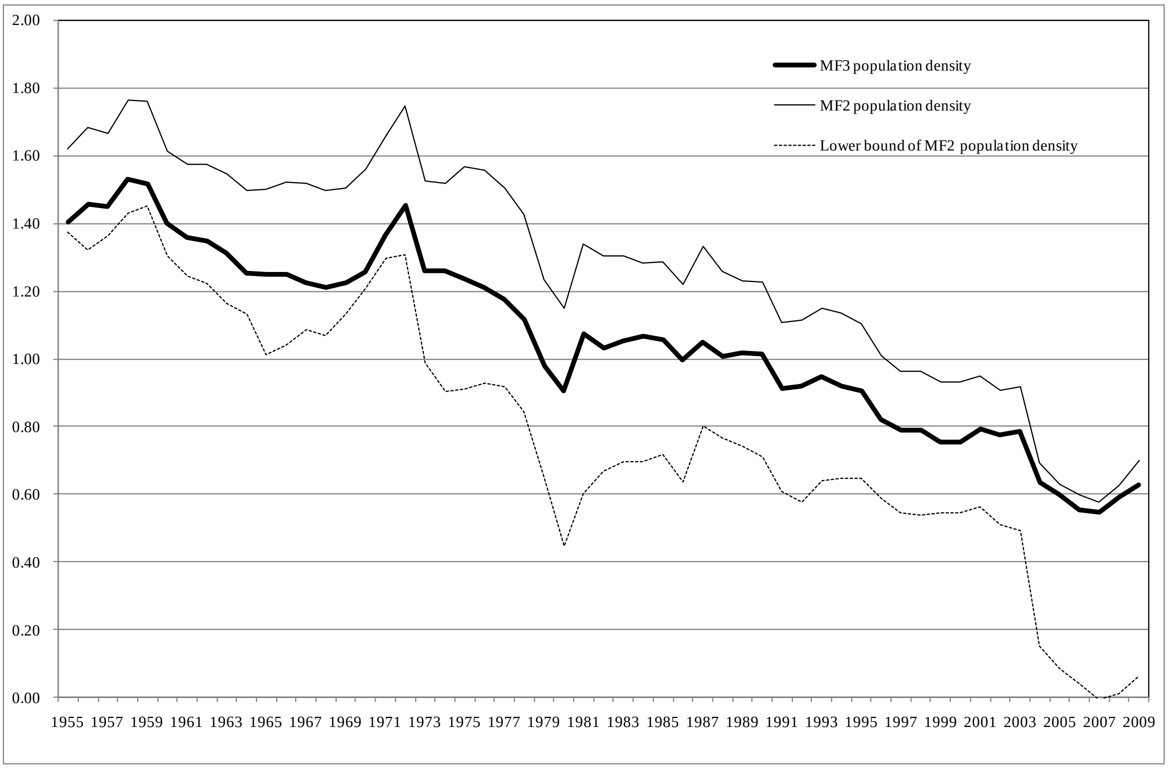


Chart 27: GPE Elasticity of MF3: Pooling Estimates

	GPE		Percentage share of primary industry		Population density		Percentage share of the service industry		The share of the population aged 65 years or older		Observations
1955-2009	1.295***	(0.0299)									2,530
	0.923***	(0.0350)	-0.0216***	(0.00125)							2,530
	1.137***	(0.0288)			0.0536***	(0.00465)					2,530
	1.276***	(0.0274)					0.0156***	(0.00151)			2,530
	0.878***	(0.0324)	-0.0196***	(0.00123)	0.0273***	(0.00449)					2,530
	0.881***	(0.0289)	-0.0228***	(0.00118)			0.0185***	(0.00135)			2,530
	1.137***	(0.0281)			0.0482***	(0.00465)	0.0135***	(0.00153)			2,530
	0.853***	(0.0288)	-0.0215***	(0.00117)	0.0178***	(0.00428)	0.0176***	(0.00135)			2,530
1970-2009	1.125***	(0.0380)							0.00221	(0.00178)	1,840
	0.867***	(0.0441)	-0.0289***	(0.00184)					0.0127***	(0.00159)	1,840
	1.115***	(0.0350)					0.0116***	(0.00176)	0.000982	(0.00176)	1,840
	0.915***	(0.0330)			0.104***	(0.00575)			0.0272***	(0.00205)	1,840
	0.783***	(0.0372)	-0.0214***	(0.00184)	0.0747***	(0.00588)			0.0279***	(0.00196)	1,840
	0.920***	(0.0332)			0.100***	(0.00574)	0.00348*	(0.00166)	0.0259***	(0.00201)	1,840
	0.812***	(0.0344)	-0.0330***	(0.00182)			0.0190***	(0.00167)	0.0122***	(0.00156)	1,840
	0.768***	(0.0339)	-0.0263***	(0.00188)	0.0541***	(0.00548)	0.0131***	(0.00166)	0.0234***	(0.00186)	1,840
1955-2003	1.342***	(0.0309)									2,254
	0.972***	(0.0368)	-0.0200***	(0.00125)							2,254
	1.202***	(0.0299)			0.0477***	(0.00513)					2,254
	1.322***	(0.0284)					0.0149***	(0.00161)			2,254
	0.937***	(0.0344)	-0.0185***	(0.00124)	0.0214***	(0.00498)					2,254
	0.921***	(0.0312)	-0.0214***	(0.00120)			0.0183***	(0.00145)			2,254
	1.196***	(0.0292)			0.0433***	(0.00512)	0.0134***	(0.00163)			2,254
	0.902***	(0.0311)	-0.0204***	(0.00119)	0.0128**	(0.00476)	0.0177***	(0.00144)			2,254
1970-2003	1.190***	(0.0407)							0.00421*	(0.00201)	1,564
	0.920***	(0.0472)	-0.0267***	(0.00183)					0.0147***	(0.00178)	1,564
	1.178***	(0.0379)					0.00990***	(0.00196)	0.00303	(0.00199)	1,564
	0.987***	(0.0361)			0.0937***	(0.00630)			0.0263***	(0.00225)	1,564
	0.845***	(0.0408)	-0.0205***	(0.00188)	0.0638***	(0.00650)			0.0273***	(0.00214)	1,564
	0.989***	(0.0364)			0.0906***	(0.00625)	0.00336	(0.00186)	0.0252***	(0.00218)	1,564
	0.855***	(0.0378)	-0.0310***	(0.00185)			0.0184***	(0.00187)	0.0142***	(0.00175)	1,564
	0.819***	(0.0374)	-0.0256***	(0.00193)	0.0437***	(0.00601)	0.0138***	(0.00184)	0.0230***	(0.00202)	1,564
2004-2009	0.815***	(0.102)									276
	0.509***	(0.120)	-0.0786***	(0.00795)							276
	0.591***	(0.0847)			0.0828***	(0.00972)					276
	0.833***	(0.0802)					0.0154***	(0.00394)			276
	0.484***	(0.106)	-0.0576***	(0.0119)	0.0396**	(0.0140)					276
	0.496***	(0.0787)	-0.0887***	(0.00810)			0.0224***	(0.00413)			276
	0.617***	(0.0810)			0.0767***	(0.00970)	0.00789*	(0.00386)			276
	0.498***	(0.0786)	-0.0903***	(0.00942)	-0.00277	(0.0103)	0.0229***	(0.00419)			276
	0.777***	(0.106)							-0.00689*	(0.00345)	276
	0.518***	(0.122)	-0.104***	(0.00880)					0.0195***	(0.00353)	276
	0.790***	(0.0847)					0.0158***	(0.00401)	-0.00774*	(0.00342)	276
	0.601***	(0.0784)			0.141***	(0.0110)			0.0300***	(0.00428)	276
	0.461***	(0.0928)	-0.0769***	(0.0107)	0.101***	(0.0148)			0.0389***	(0.00437)	276
	0.602***	(0.0808)			0.141***	(0.0111)	0.0000487	(0.00374)	0.0300***	(0.00441)	276
	0.505***	(0.0787)	-0.118***	(0.00790)			0.0237***	(0.00398)	0.0216***	(0.00347)	276
	0.474***	(0.0783)	-0.0956***	(0.00973)	0.0641***	(0.0126)	0.0151***	(0.00414)	0.0331***	(0.00435)	276

Note: Numbers in parentheses are heteroskedasticity-robust standard errors. *, **, and *** indicate statistical significance at 5%, 1%, and 0.1 % level.