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MONETARY POLICY WITH LIQUIDITY FRICTIONS

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Abstract

This paper explores the welfare effects of a reduction in the inflation rates in an environment of incomplete markets. We built a dynamic heterogeneous agent model that features idiosyncratic risks in the labor supply and liquidity frictions. The model shows that a disinflation policy results in an income reallocation among debtors and lenders. The changes in the capital returns conveys variations in the precautionary savings and hence, an intertemporal redistribution of wealth and income. The welfare implications are develop according to the incomplete market features and the money plays a role of smoothing consumption when the agents faces income variability without state contingent insurance. The model is calibrated for the Colombian economy in such a way that disinflation episodes are replicated. Early results show that the disinflation monetary policy leads to improvements of liquidity in the economy because the money holdings are used by the agents for wealth transfer over time. This paper shows quantitative evidence in which disinflation facts are associated with increments in the average real money holdings and average consumption. In addition, the volatility of consumption is reduced as the inflation rate falls, while the volatility of money holdings increases (i.e. precautionary demand for money balance).

Key words: monetary policy, heterogeneous agents, stationary distribution.

JEL Classification: E40, E31.

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POLÍTICA MONETARIA CON FRICCIONES DE LIQUIDEZ

Resumen

Este artículo analiza los efectos sobre el bienestar de una reducción de la tasa de inflación en un ambiente de mercados incompletos. Se construye un modelo de agentes heterogéneos con fricciones de liquidez y riesgos idiosincráticos en la oferta de trabajo. Este modelo muestra como una política desinflacionaria produce cambios en la distribución del ingreso entre deudores y acreedores. Cambios en los retornos del capital inducen cambios en el ahorro precautelativo y por lo tanto un redistribución intertemporal de la riqueza y el ingreso. Las implicaciones de bienestar son desarrolladas acorde con las características de mercados incompletos y el dinero juega el papel de suavizamiento del consumo cuando los agentes enfrentan variabilidad del ingreso sin un esquema de aseguramiento estado- contingente. El modelo es calibrado para Colombia de tal manera que los principales episodios de desinflación son replicados. Los primeros resultados muestran como la política monetaria desinflacionaria conlleva a mejoras en la liquidez de la economía porque el dinero es usado para transferir riqueza a través del tiempo. En este artículo se muestra evidencia cuantitativa que los hechos desinflacionarios son asociados a incrementos en la tenencia de saldos reales y consumo promedio. Adicionalmente, la volatilidad del consume se reduce a medida que la inflación disminuye, mientras la volatilidad de los saldos reales se incrementa. (i.e. Demanda precautelativa por dinero).

Palabras clave: política monetaria, agentes heterogéneos, distribución estacionaria.

Clasificación JEL: E40, E31.

1 Introduction

The central objective of this paper is to analyze the effect of the monetary policy in an economy where the liquidity provision is inefficient. Specifically, this paper discuss the quantitative implications of the monetary policy based on controlling interest rates (Wicksellian and Taylor policies) on the income distribution and wealth. The exposition is based on the models of Abel [1985], Aiyagari [1994], Aiyagari-Getler[1998]. A cash in advance model with heterogenous agents is constructed, in which the money is used for consumption and accumulation by large number of agents, who are subject to idiosyncratic shocks. The transaction costs of trading assets is introduced as in the spirit of Aiyagari-Getler. Therefore, the cost of trading becomes a relevant variable for explaining the behavior of assets prices.

The theoretical structure of the model is based on the framework of Bewley [1977], Clarida [1985], Schechtman [1976], where the agents hold liquid assets to self-insure against the "income fluctuation problem". The liquidity assets enable the agents to smooth their consumption. In this sense, the agents accumulate liquidity assets during boom periods that will provide consumption in periods when the agents are unemployment.

A fist contribution in this way was Imorohoroglu [1992] who studies the welfare effects of inflation under imperfect insurance and finds that welfare costs of inflation measure as the area under the empirical money demand curve is a poor measure, because it ignores the effects of volatility of consumption and money holdings when the markets are incomplete.

Kocherlakota [2003] built a model with limited enforcement where the agent cannot borrow and is subject to preferences shocks. In this model, the optimal monetary policy is characterized by the sheding of bonds when cross-sectional variance of marginal utility is high. The main idea is that the monetary authority can redistribute liquidity from agents with low marginal utility with respect to agents with low endowments shocks.

Akyol [2003] constructed a general dynamic incomplete market equilibrium model with liquid money and illiquid assets. The money is valued because of a timing friction in the bond market. The model shows that the inflation rate transfer resources from the agents with high endowments to those holding bonds. The welfare implications show that the optimal allocation depends on the positive credit held by households.

Algan and Ragot [2004] creates a model with heterogenous agents and borrowing constraints, in this model the welfare effects between two types of economies constrained and unconstrained are begin when the policy maker follow a quantity money creation rule like by the government collecting all revenues from the inflation tax. They found that the inflation cost is smaller in incomplete market compared to a complete market.

Several papers showed the importance of re-distributive effects of the monetary policy, Palivos [2004] constructed a model where agents have different altruistic preferences and the inflation affects the optimal path of capital accumulation. In this model the Friedman rule is not optimal. A similar result is obtained by Aiyagari y Williamson [1997], who found an economy with asymmetric information where the Friedman rule is optimal, however with incomplete markets a positive rate of inflation is optimal.

Within the Colombian literature Partow [1995], Posada [1997], Riascos [1998], Hamman-Restrepo [2004], Restrepo [2005] have emphasized the distortions generated by the inflation tax and calculated the impact on the allocations of resources. In all models the money is used as medium of exchange but they ignore the relevance of asset money-asset demand and the roll of smoothing consumption fluctuations.

The model presented in this paper is closely related to Imorohoroglu [1992], Aiyagari and Geltler [1998] and Akyol [2003] in order to shed light about the welfare implications of disinflation process under liquidity frictions. The studies on liquidity effects are relevant in order to understand the roll of the interest rate monetary policy transmission. The excellent survey of Edmond and Weill [2005] shows how the liquidity frictions are associated to timing in the asset market. In this paper the impact of the money supply policy on the interest rate is analyzed and explain the implications in the short and long run.

The main contribution of this paper is to extend the previous results in such way that they include active interest rate policy. In this paper, two schemes of monetary policy are compared: monetary supply rules and inflation targeting, and the effects on the welfare in both scenarios are addressed. A model with heterogeneous agents where the demand of money depend on the state on the economy is proposed. According to that, a timing friction is introduced when the agents exchange assets between them. The model tries to replicate the volatility of the short and real nominal interest rate and compare the welfare effects behind two regimes of the monetary policy.

Preliminary results showed that the disinflation monetary policy leads to improve the liquidity in the economy because money holdings are used by agents to transfer wealth over time. This paper shows quantitative evidence that disinflationary process are accompanied by increments in the average real money holdings and average consumption. In the same manner, the volatility of consumption is reduced as the inflation rate falls, while the volatility of money holdings increases. That is, accordance with the intuition under precautelative demand for money balance [see Dreze and Modogliani 1972].

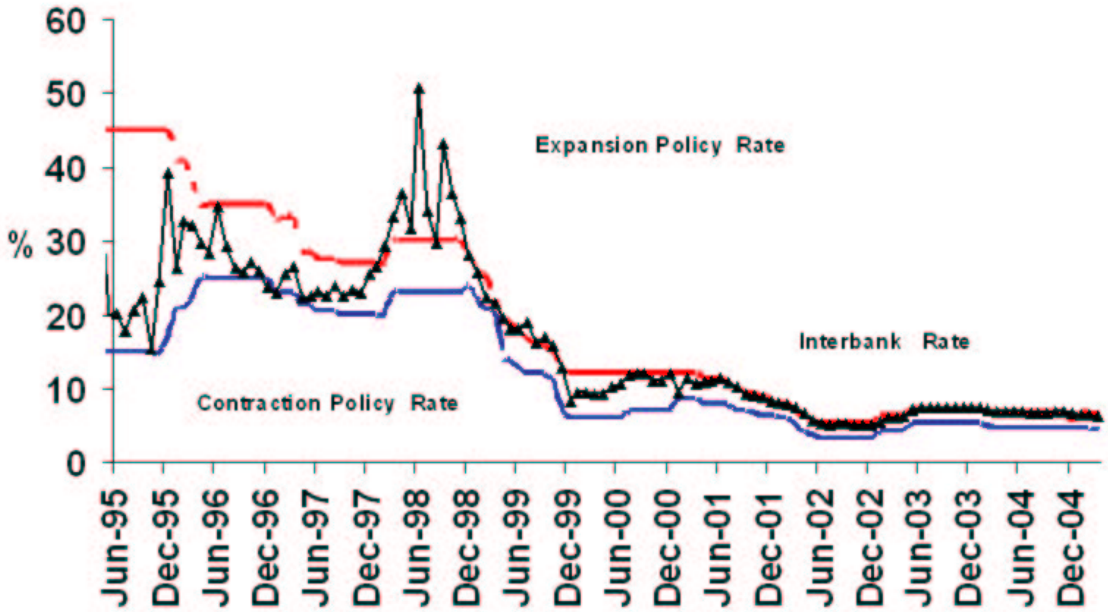
The structure of the paper is as follow: The stylized facts are presented in the section II. In section III the structure of the model is presented. In section IV the stationary equilibrium and distribution is characterized. The calibration and parametrization are explained in the section V. In section VI the results are presented. Some concluding remarks are the given in Section VII.

2 Stylized Facts

In any case, the monetary policy is associated with the quantity of liquidity in the economy. The main policy instrument for liquidity is called "Colombian Central Bank Intervention Rates", which are the expansion and contraction rates. According to the Colombian data, the periods where the inflation targeting was implemented, the gap between expansion and contraction rates was reduced to 12% in one decade. Nevertheless, the difference between loan and saving rates increases to higher levels, around 10% between 1998 and 2005, which reflects a rise in the intermediation cost of the financial sector. The intermediation cost in Colombia is on an average, more than two times that of the cost in the developed countries (which is around 4%).

These facts are associated to the accumulation process as savings decisions are altered in presence of liquidity constraints Zeldes [1994]. According to the Colombian facts, using

Figure 1: Policy Rates



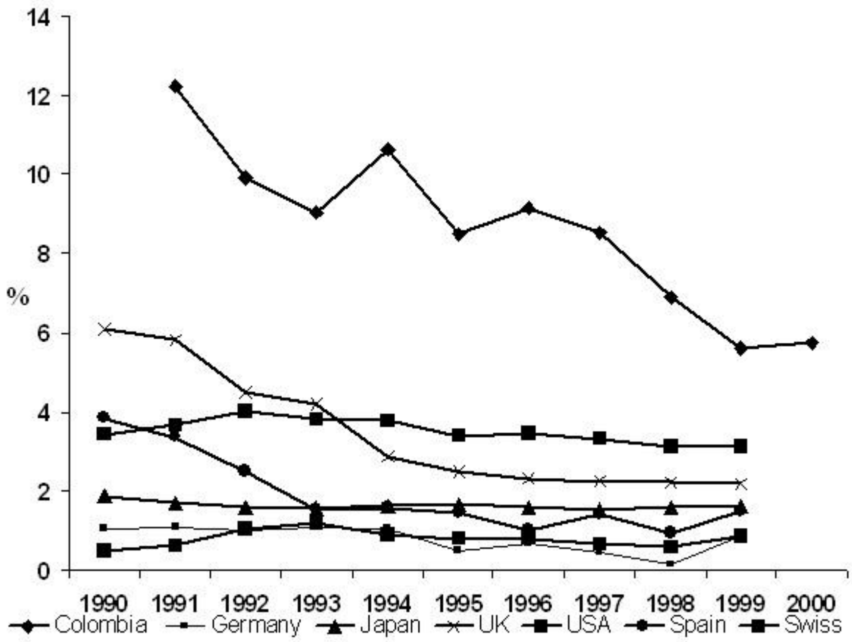
the Quality of Life Survey for 2003, the households with low and middle income own the 10% and 18% of holdings assets, while households with high income own the 63%. With respect to financial assets, the General Media Survey for 2000 showed that the main financial holdings by households with low income are saving accounts and debit cards (32% and 20% respectively). As for households with middle income, the savings accounts and debit card are the main financial holdings but the share of credit as financial holdings increased 22%. In the case of households with high income, the composition of financial assets is similar to middle income group.

3 Model

3.1 The individual's problem

Following the model proposed by Aiyagari and Geltler [1998], we built a cash-in- advance model with idiosyncratic risks and transaction costs. The economy is composed by a

Figure 2: Financial Cost: International Comparison



collection of agents (I), which are endowed with private bond claims (b^i), inelastic labor units which are normalized to 1, and money (M^i). The labor income is random, non-correlated across the individuals and obey the Markov stochastic process at follow:

$$F(\varepsilon_{t+1}, \varepsilon) = prob\left[\varepsilon_{t+1} = \varepsilon' | \varepsilon_t = \varepsilon\right]$$

Where $\varepsilon \in \{\varepsilon^e, \varepsilon^u\}$, denotes the probability of remaining employment or unemployment depending on the last state.

Since the individual labor market is risky, individuals would like to purchase a securities against the possibility of receiving a drop in income. We assume that this insurance does not exist and therefore the labor market is incomplete. The assets holdings are subject to different realizations of a stochastic variable, that is grid as $Z = [0 < b_1 < b_2 <, .. < b_n]$. In this sense, the consumption plans are a result of the intertemporal trade between agents. The intermediation of assets is costless in the money market and individuals can hold money accounts. The money enters as a medium of exchange via cash-in-advance constraint, which is used to purchase consumption goods and nominal assets. The economy is defined as[1] $\Xi : \left\langle \left\{ (u_t^i, b_t^i, M_t^i)_{t=0}^{\infty} \right\}_{i\in I} | \varepsilon_t = \varepsilon \right\rangle$.

The problem to be solved by each agent is:

$$\max_{\left\{c_t^i, M_{t+1}^i, b_{t+1}^i\right\}_{t=0}^{\infty}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t u(c_t^i) \right\}$$

subject to:

$$c_t^i + \frac{M_{t+1}^i}{p_{t+1}} + b_{t+1}^i = (1+r)\, b_t^i + w_t^i \varepsilon + \frac{M_t^i + T_t^i}{p_t} \quad \veebar\, i \tag{1}$$

$$c_t^i + \left(b_{t+1}^i - b_t^i\right) \leq \frac{M_t^i - T_t}{p_t} - \phi_b \left(b_{t+1}^i - b_t^i\right) \ if \ \varepsilon = e \tag{2}$$

$$c_t^i + \left(b_{t+1}^i - b_t^i\right) \leq \frac{M_t^i - T_t}{p_t} - \phi_s \left(b_t^i - b_{t+1}^i\right) \ if \ \varepsilon = u \tag{3}$$

with

$$c_t^i \geq 0, b_{t+1}^i \geq -\theta$$

Where c^i, M^i, b^i, are the individual consumption, money and assets holdings respectively. The w^i, p, r are the prices of labor, consumption goods, and the rental price of capital. The last one is free-risk. (T) denotes the nominal transfers that each individual receives. ϕ is the transaction cost when the agents buy or sell assets. θ is a debt limit that guarantees that $(c_t^i \geq 0)$. Note that both frictions introduced (The borrowing constraint and the transactions cost) depend on the different accrual of labor income. If the individual receives high income, he would like to lend to another individual with low income. In addition, if an individual desires to borrow or lend there is a liquidity cost which is proportional to the size of trade. Wherever individuals use money for exchange

[1] Posible extension of this model is consider a Sidaruki representation which is well exposed in Heer [2004] and Algan and Ragot [2006]. The Sidraski model with heterogenous agents is debt contraint. The model present here considers frictions as well debt limits and prices and therefore the Sidrauski model is not analyzed in this paper.

or if the liquidity constraint is active, depending on the nature state. As a matter of fact, if agents desire to buy assets, the cash-in advance constraint can be expressed:

$$c_t^i + (1+\phi)\left(b_{t+1}^i - b_t^i\right) \leq \frac{M_t^i - T_t}{p_t}$$

If agents desire to sell assets, the cash in advance is:

$$c_t^i + (1-\phi)\left(b_{t+1}^i - b_t^i\right) \leq \frac{M_t^i - T_t}{p_t}$$

3.2 Optimal Conditions

The optimal intertemporal allocations are the portfolio composition between money, assets or debt. The control variables are consumption and money, the state variable are the assets in the future. The programming problem that each agent has to solve is:

$$V^i(b, M, \varepsilon) = \max_{c, M', b'} \; u(c^i) + \beta \int V^i\left(b', M', \varepsilon'\right) dF(\varepsilon'; \varepsilon)$$

subject to:

$$\begin{aligned}
c_t^i + \frac{M_{t+1}^i}{p_{t+1}} + b_{t+1}^i &= (1+r)\, b_t^i + w_t^i \varepsilon + \frac{M_t^i + T_t}{p_t} \quad \veebar\, i \\
c_t^i + \left(b_{t+1}^i - b_t^i\right) &\leq \frac{M_t^i + T_t}{p_t} - \phi\left(b_{t+1}^i - b_t^i\right) \; if \; \varepsilon = e \\
c_t^i + \left(b_{t+1}^i - b_t^i\right) &\leq \frac{M_t^i + T_t}{p_t} - \phi\left(b_t^i - b_{t+1}^i\right) \; if \; \varepsilon = u
\end{aligned}$$

with

$$c_t^i \geq 0, a_{t+1}^i \geq -b$$

The first order conditions are:

$$\left[c^i\right] \quad : \quad E_t\left\{u_c(c_t)\right\} = \lambda_{1t} + \lambda_{2t} \tag{4}$$

$$\left[M^i\right] \quad : \quad \frac{p_t}{p_{t+1}}\beta\left(\lambda_{1t+1} + \lambda_{2t+1}\right) = \lambda_{1t} \tag{5}$$

$$\left[b^i\right] \quad : \quad \beta\left\{(1+r)\lambda_{1t+1} + \lambda_{2t+1}\left[(1+\phi)\right]\right\} = \lambda_{1t} + \lambda_{2t}\left[(1+\phi)\right] \qquad if\ \varepsilon = e \tag{6}$$

$$\left[b^i\right] \quad : \quad \beta\left\{(1+r)\lambda_{1t+1} + \lambda_{2t+1}\left[(1-\phi)\right]\right\} = \lambda_{1t} + \lambda_{2t}\left[(1+\phi)\right] \qquad if\ \varepsilon = u \tag{7}$$

Where are the Lagrange multipliers associated to each constraint. The Euler equation for this problem is (if the agent is buyer):

$$(1+\phi)\,u_c(c_t) \geqslant \frac{\beta^2}{\pi_{t+2}}\left\{E\left\{u_c(c_{t+2})\right\}[r-\phi] + E\left\{u_c(c_{t+1})\right\}\beta(1+\phi)(ind(e) - ind(u))\right\} \tag{8}$$

where ind(e) and ind(u) are the indicator function that take the value one if the agent is employed or unemployed in the period t and zero otherwise :

$$ind(e) = \left\{\begin{array}{ccc} 1 & if & \varepsilon = e \\ 0 & if & \varepsilon = u \end{array}\right\}$$

and

$$ind(u) = 1 - ind(e)$$

The equation 8 shows the benefit and cost of consuming one less unit at time t and using the cash to increase a_{t+1} by unit. Note that the benefits are affected by the transaction costs which alter the return of assets. On the other hand, the inflation rate reduced the future consumption for each individual, therefore the savings decisions are affected by liquidity frictions and the inflation level.

In order for the individuals to smooth their consumption facing a fluctuating income, the individuals hold on to the liquidity from assets to prevent the individual form suffering consumption reduction caused by lower income realizations. Behind the incomplete market framework, the liquidity provision is inefficient. In this sense the monetary policy could be a risk-sharing of liquidity and improve the allocation of resources.

3.3 Monetary Policy

Let $\psi_0 = \frac{U_c(t)}{U_c(t+1)}$ and $\psi_1 = \frac{U_c(t+2)}{U_c(t+1)}$ then the Euler condition could be re-written as follows:

$$(1+\phi)\int \psi_0 dF(\varepsilon';\varepsilon) \geqslant \frac{\beta^2}{\pi_{t+2}}\int \psi_1 dF(\varepsilon';\varepsilon)\left[r-\phi\right] + \beta(1+\phi)(ind(e)-ind(u))$$

In the steady-state the Euler condition satisfies the following condition:

$$\widetilde{\pi} = \frac{\beta^2\left(r-\phi\right)}{((1+\phi)(1-\beta(ind(e)-ind(u)))}$$

If the nominal interest rate is defined as $r^n = r - \pi$ the optimal level of inflation is:

$$\widetilde{\pi} = \frac{\beta^2\left(r^n-\phi\right)}{((1+\phi)(1-\beta(ind(e)-ind(u))) + \beta^2}$$

In the model of Kehoe and Levine [2000] the restrictions are called short sales and it is difference of the debt constrained market because dynamic properties in the first case are more complicated in the stochastic environment instead of the second model. In the model presented here, is a non-stochastic model and own properties of the equilibrium are according with Kehoe and Levine [2000](see pag 7-8)

In this model a Taylor program is consider: The central bank responds to deviations from target levels. For simplicity we assume that transaction cost is equal between buyer and sellers as characterized in the optimal conditions.

In this sense, a Taylor program is defined as follow: The central bank chooses $r^n = \varphi\left(\frac{\pi_t}{\pi*};\varepsilon\right)$ such that:

$$\widetilde{\pi} = \frac{\beta^2\left(\varphi\left(\frac{\pi_t}{\pi*};\varepsilon\right)-\phi\right)}{((1+\phi)(1-\beta(ind(e)-ind(u))) + \beta^2}$$

The monetary policy is solution to the Euler equation described above, the monetary policy affect the liquidity of the economy. The existence of a solution offered by of the different monetary programs described above is characterized through the existence of the fix point solution for different schemes. We assume that the monetary policy function is a continuous function, then different programs are:

$$\pi^* \varphi\left(\frac{\pi}{\pi *}; \varepsilon\right) \varphi^{-1}\left(\frac{\pi}{\pi *}; \varepsilon\right) = \frac{\beta^2\left(\varphi\left(\frac{\pi_t}{\pi *}; \varepsilon\right) - \phi\right)}{((1+\phi)(1-\beta(ind(e) - ind(u))) + \beta^2}$$

Then $f\left(\varphi\left(\frac{\pi_t}{\pi *}; \varepsilon\right)\right) = \pi^* \varphi\left(\frac{\pi}{\pi *}; \varepsilon\right) \varphi^{-1}\left(\frac{\pi}{\pi *}; \varepsilon\right)$ therefore:

$$f\left(\varphi\left(\frac{\pi_t}{\pi *}; \varepsilon\right)\right) = \frac{\beta^2\left(\varphi\left(\frac{\pi_t}{\pi *}; \varepsilon\right) - \phi\right)}{((1+\phi)(1-\beta(ind(e) - ind(u))) + \beta^2}$$

Let $\Delta_1 = \frac{\beta^2}{((1+\phi)(1-\beta(ind(e)-ind(u))) + \beta^2}$

$$f\left(\varphi\left(\frac{\pi_t}{\pi *}; \varepsilon\right)\right) = \Delta_1\left(\varphi\left(\frac{\pi_t}{\pi *}; \varepsilon\right) - \phi\right)$$

To study the existence of solutions to last equation, the operator T is defined in the functions $f : \delta \to R_{++}$where $\varphi\left(\frac{\pi_t}{\pi *}; \varepsilon\right) \in \delta$ Then we need to ensure that the operator T is a contraction mapping and after the Banach fixed point properties provides sufficient conditions in order to prove the monetary solution.

Using the Euclidean metric, Let $T : \varphi\left(\frac{\pi_t}{\pi}\right) \to \varphi\left(\frac{\pi_t}{\pi}\right)$ be defined by $T\varphi\left(\frac{\pi_t}{\pi}\right) = \varphi\left(\frac{\pi_t}{\pi}\right)$, Therefore for any two points $d(T\varphi\left(\frac{\pi 1}{\pi^*}\right), T\varphi\left(\frac{\pi_2}{\pi^*}\right)) = \frac{1}{\pi *} d\left(\varphi\left(\frac{\pi 1}{\pi}\right), \varphi\left(\frac{\pi_2}{\pi}\right)\right)$ then T is a contraction with modulus $\frac{1}{\pi^*}$

4 Stationary Equilibrium

Let (χ, B, ψ) be a probability space where (B) is a $\sigma-$suitable algebra on χ and ψ a probability measure.

Definition 3: A stationary equilibrium for a given set $\left\{\varphi\left(\frac{\pi}{\pi *}; \varepsilon\right) \; or \; \varphi\left(\frac{p}{p *}; \varepsilon\right)\right\}$ of monetary policy is a value function $V^i(a, b, \varepsilon)$, individual policy rules for consumption $c(a, b, \varepsilon)$, demand for money in the next period $M'(a, b, \varepsilon)$ and assets $a'(a, b, \varepsilon)$ in the next period. Time- invariant distribution of state variable x=(a, b, ε), and a vector of time invariant prices $\{p, w, r\}$, and a vector of aggregates variables (A, b) such that:

- Given $\{p, w, r\}$ the invariant prices $c(a, b, \varepsilon), b'(a, b, \varepsilon), a'(a, b, \varepsilon)$ are the optimal decisions rules and solve the following problem:

$$V^i(a, b, \varepsilon) = \max_{c, M', b'} u(c^i) + \beta \int V^i(a', b', \varepsilon')\, dF(\varepsilon'; \varepsilon)$$

  subject to:

$$\begin{aligned} c_t^i + \frac{M_{t+1}^i}{p_{t+1}} + b_{t+1}^i &= (1+r)\, b_t^i + w_t^i \varepsilon + \frac{M_t^i + T_t}{p_t} \quad \veebar i \\ c_t^i + \left(b_{t+1}^i - b_t^i\right) &\leq \frac{M_t^i + T_t}{p_t} - \phi_b \left(b_{t+1}^i - b_t^i\right) \ if\ \varepsilon = e \\ c_t^i + \left(b_{t+1}^i - b_t^i\right) &\leq \frac{M_t^i + T_t}{p_t} - \phi_s \left(b_t^i - b_{t+1}^i\right) \ if\ \varepsilon = u \end{aligned}$$

  with

$$c_t^i \geq 0, b_{t+1}^i \geq -\theta$$

- The aggregates of consumption, assets and money are obtained adding-up over households:

$$\begin{aligned} Z &= \int_\chi b^i d\psi \\ \overline{M} &= \int_\chi M^i\left((b, M, \varepsilon)\right) d\psi \\ C &= \int_\chi c^i\left((b, M, \varepsilon)\right) d\psi \end{aligned}$$

- The market clearing condition:

$$C + \left(\frac{M}{p}\right)' + Z' = Y$$

- The measure of household is stationary

$$\psi(B) = \int_X 1_{(\epsilon', a', M')} \upsilon(\varepsilon' | \varepsilon)\, d\psi$$

5 Calibration

For computing the equilibrium in this type of the economies, firstly it is required to calculate the invariant transition probabilities for different states of the economy (i.e employment and unemployment). Other parameters as the impatient rate, risk aversion and income levels are taken as exogenous according with the Colombian literature. As described above, the individual employment state is assumed to follow a first-order Markov process. After the Tauchen methodology is used in order to obtain transition probabilities matrix:

$$P = \begin{pmatrix} p_{uu} & p_{eu} \\ p_{uc} & p_{ee} \end{pmatrix} = \begin{pmatrix} 0.9280 & 0.0720 \\ 0.8446 & 0.1554 \end{pmatrix}$$

According to that, the ergodic transition matrix, is defined by ($L = \lim_{n\to\infty} P^n$), hence for this case it is ergodic matrix is:

$$L = \begin{pmatrix} 0.0800 & 0.9200 \\ 0.0800 & 0.9200 \end{pmatrix}$$

The invariant transition matrix in order to depict the employment in each state it is necessary to calculate the policy function. This data is according to duration of unemployment of 40 weeks and rate of employment equivalent to the ratio between occupied to PET which is 0.53, therefore N= 0.53. In this sense, we need to characterize the invariant wealth and income distribution and apply the algorithm suggested by Imorohoroglu [1989]:

- *Step 1*: Specification of state-space. In this case the state variables are the quantity of money and assets in the future, the employment status. A grid on the Assets and Money spaces is used for calculation of policy rules.

- *Step 2*: The computation of the value function and decision rules for holding assets or money using the ergodic Markov chain. The methodology is based on the iteration of value function until convergence to invariant joint distribution.

- *Step3:* With the distribution of consumption, assets and money holdings is estimed with invariant distribution.

The preferences are modeled by the parametrical function:

$$u(c_t) = \left(\frac{c_t^{1-\gamma}}{1-\gamma} \right), \gamma = 4, \beta = 0.96$$

The average working time is according to average quantity of labor, that is 0.33. The monetary aggregated used is M1 which is different form other papers for Colombia as in Carrasquilla [1994] and Posada [1995]. Velocity of Money M1 equal to average during 1950-2004, PY/M = 3.86 used the Colombian data provide by Banco de la Republica de Colombia statistics. The assets holdings are equal to aggregate capital stock in the economy used the historical data of DNP. The ratio M/P is based on the historical series of Banco de la Republica of Colombia.

K	M/P	N
2.4	0.12	0.53

6 Computational Experiments and Results

The computable model, replicates the main episodes of the inflation in Colombian economy. Behind inflation target scheme. Two periods are highlighted, the first called moderated inflation period (1994-1998) which was characterized by gap between contraction and expansion rate on an 22% average. The second period, between (1999-2004),depicts contraction rates which were reduced in 20 percentage points.

According to that, we distinguished two types of the liquidity constraints in the two periods described above. In the first period, there was a high intermediation cost which amounts to around 12% and which was spread between loan and deposits rates. In addition, this spread variability lead to reduction in the intertemporal credit flows. In this sense, the welfare effects of inflation targeting policy was affected by the variability in the consumption and income. The results are presented as percentage change with respect to benchmark values (see the next table).

Table 1

	$\pi = 0.25$	$\pi = 0.20$	$\pi = 0.15$
Average Real Money Holding	0.162	0.206	0.275
Std Dev of Real Money Holding	0.055	0.071	0.095
Average Consumption	0.015	0.278	0.956
Std Dev of Consumption	0.159	0.149	0.134
Average Income	0.052	0.081	0.087
Std Dev of Income	0.159	0.149	0.134
Average Utility	-0.098	-0.083	-0.072
Bonds Holdings	0.091	0.124	0.175

It can be observed that a period with high inflation is associated with high variability in the consumption and income. Additionally, average money holdings are lower in the economies with high inflation rates, therefore, the agents reduced the cash balances in these periods. In the graph 2,3 and 4 the stationary distribution of money holdings is illustrated.

The intuition behind these results is that intertemporal decisions pattern rules changes of each type of agents changed with the different levels of inflation rates. The graph 5,6,7 describes the optimal policy function for each case of inflation rate. In accordance with Euler conditions (equations 8 and 9), the inflation rate alters the slope of the intertemporal marginal rate of substitution, and as illustrated in the graphs, the slope of policy function changes for each agent. In economies with high inflation the credit bonds and money values drop in transferring wealth over time.

The second period was characterized by a contraction in the economic activity in 1999 which led to quantity restrictions on the holding of assets. The variability of consumption is reduced but the variability on the real money holdings increased. This fact shows that the precautionary demand for money soars. When the inflation rate is reduced, the return of real balances is growing and the agents (depending on the state of endowment shock) prefer liquid assets in order to smooth the consumption stream. Conversely, the roll of private bonds for self-insurance behavior with respect to adverse shock is limited.

Table 2

	$\pi = 0.10$	$\pi = 0.055$	$\pi = 0.03$
Average Real Money Holding	0.4127	1.0880	2.4141
Std Dev of Real Money Holding	0.1498	0.3813	0.4272
Average Consumption	0.9638	0.9985	1.3487
Std Dev of Consumption	0.1138	0.0652	0.0487
Average Income	1.3011	1.3565	1.4828
Std Dev of Income	0.1138	0.0658	0.0779
Average Utility	-0.0558	-0.0061	0.2756
Bonds Holdings	0.241	0.387	0.451

However, under consumption-smoothing, inflation also distorts the marginal rates of substitution across agents as they face liquidity constraints, the marginal rates of substitution are different among them. At periods of contraction economy, the size of borrowing is reduced and the bond market loses the power of transferring wealth across the time. In this sense, the money is used for smoothing consumption and therefore the redistributive effects is generated by inefficiency in the liquidity provision in the economy. The graphs 8,9 illustrate this point. The disinflationary process leads to the redistribution of money holdings in the economy which implies that the liquidity risk is share by most agents. The graphs 10-12 described as the reduction of inflation leads to changes in the intertemporal consumption and in as as the money transfer wealth over time.

This model could be extended easily with capital accumulation and endogenous labor supply. In the further research will consider financial sector in the monetary channel transmission.

7 Concluding Remarks

The effects of the monetary policy based in the prices and interest rules in an economy with liquidity constraints were analyzed. For this aim, dynamic computable heterogenous agents were constructed. In this model the money is not super-neutral, hence the money has direct effects on the allocation of resources. As the agents face incomplete markets, an endogenous stationary assets-income distribution is generated. The effects on the stationary distribution when the agents facing two types of liquidity constraints is explored. The first is related to the gap between loan and deposit rates, which affects the variability of returns of assets. This friction characterized the behavior of monetary variables between 1994-1998. The second is the quantity constraints which lead to reduction in the quantity of resources available to savings and intertemporal consumption.

The results show that the disinflation periods in Colombia between 1994-2003 are associated with increments in the average real money holdings and average consumption. The volatility of consumption is reduced as the inflation rate falls, while the volatility of money holdings increases: This shows the importance of the precautionary demand for money balance in the smoothing consumption over time.

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9 Graph Appendix

Figure 3: Stationary Distribution of Money Holdings

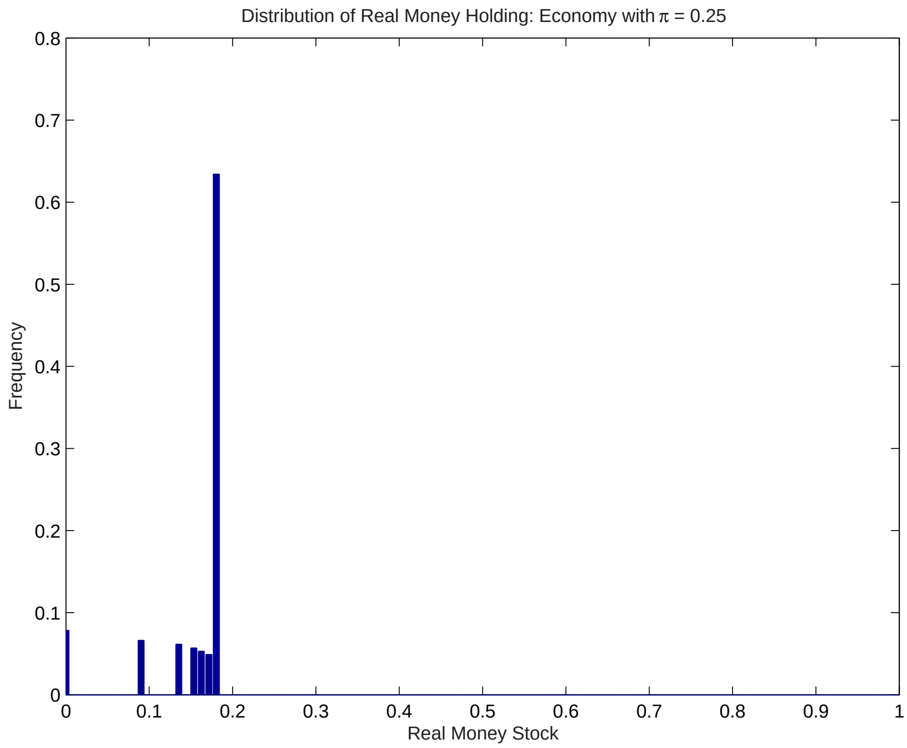

Figure 4: Stationary Distribution of Money Holdings

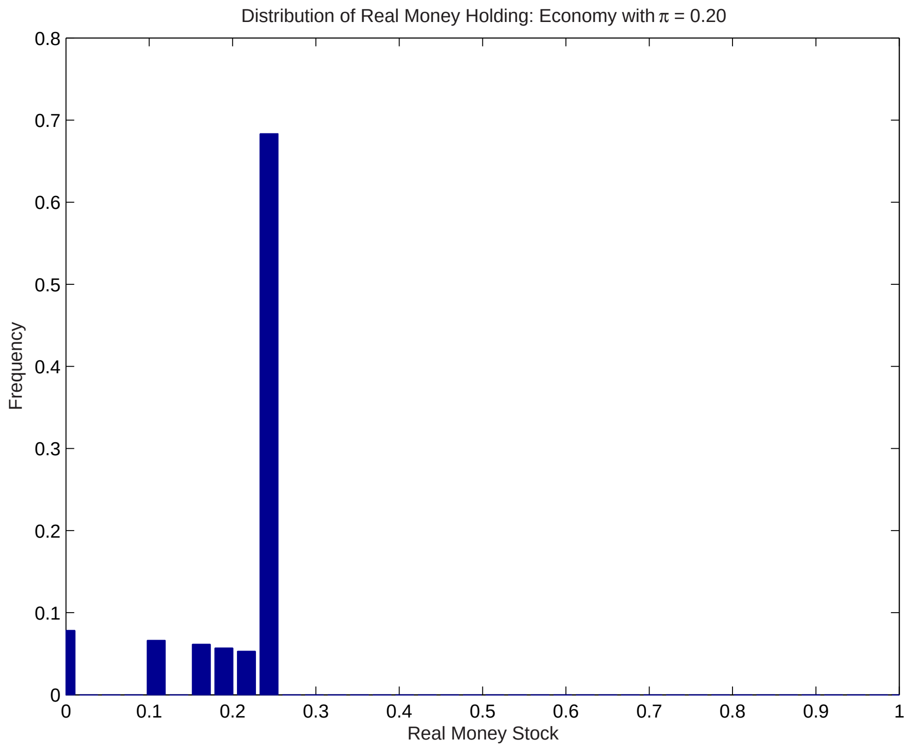

Figure 5: Stationary Distribution of Money Holdings

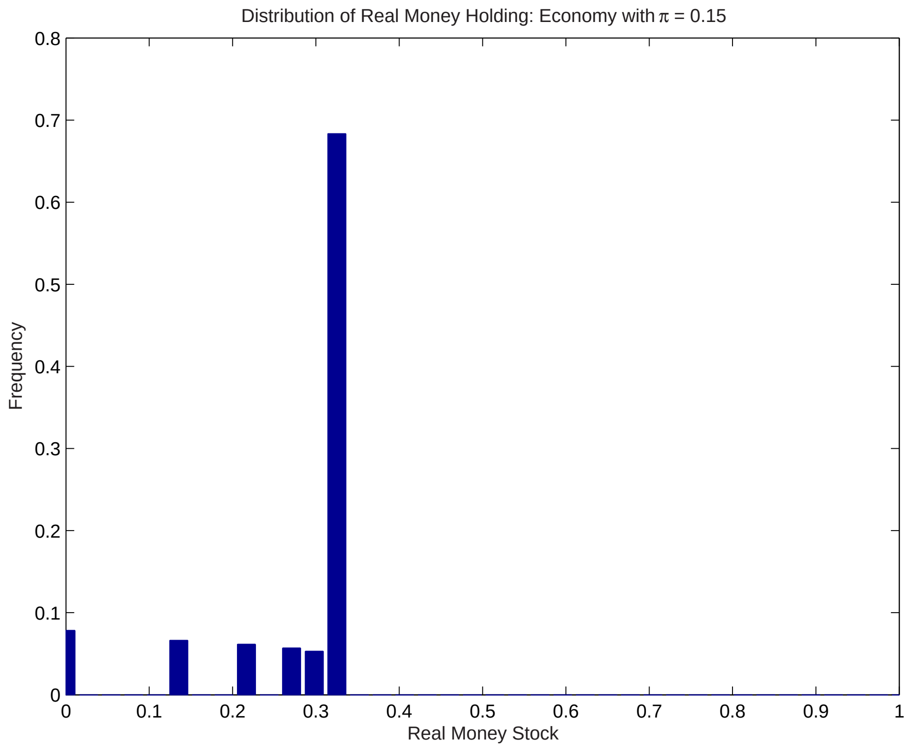

Figure 6: Policy Function with Different Employment States

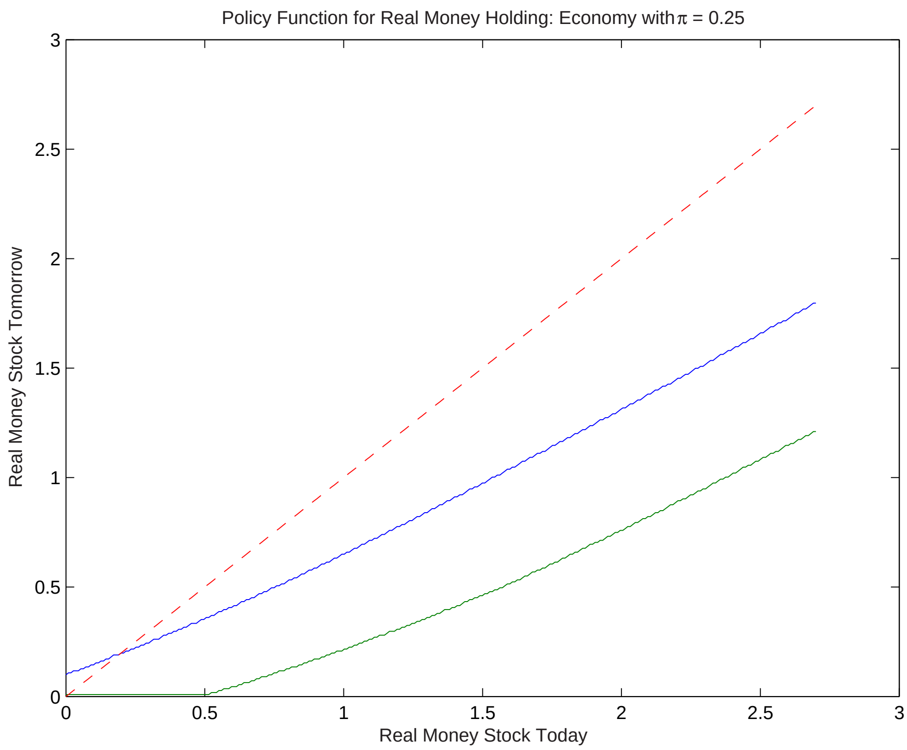

Figure 7: Policy Function with Different Employment States

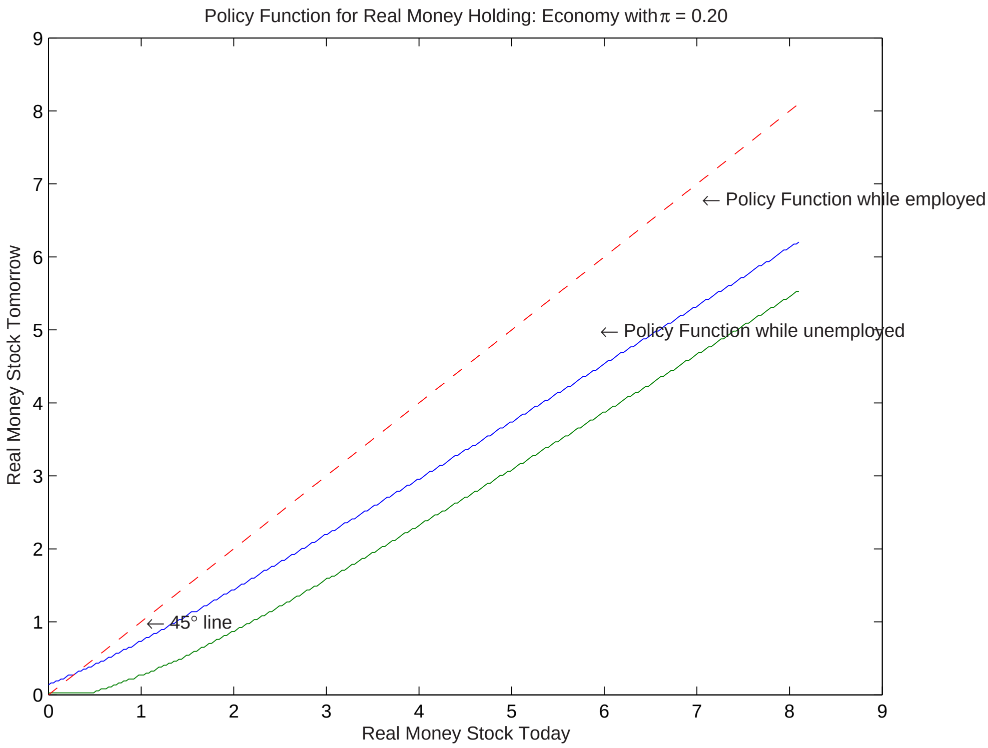

Figure 8: Policy Function with Different Employment States

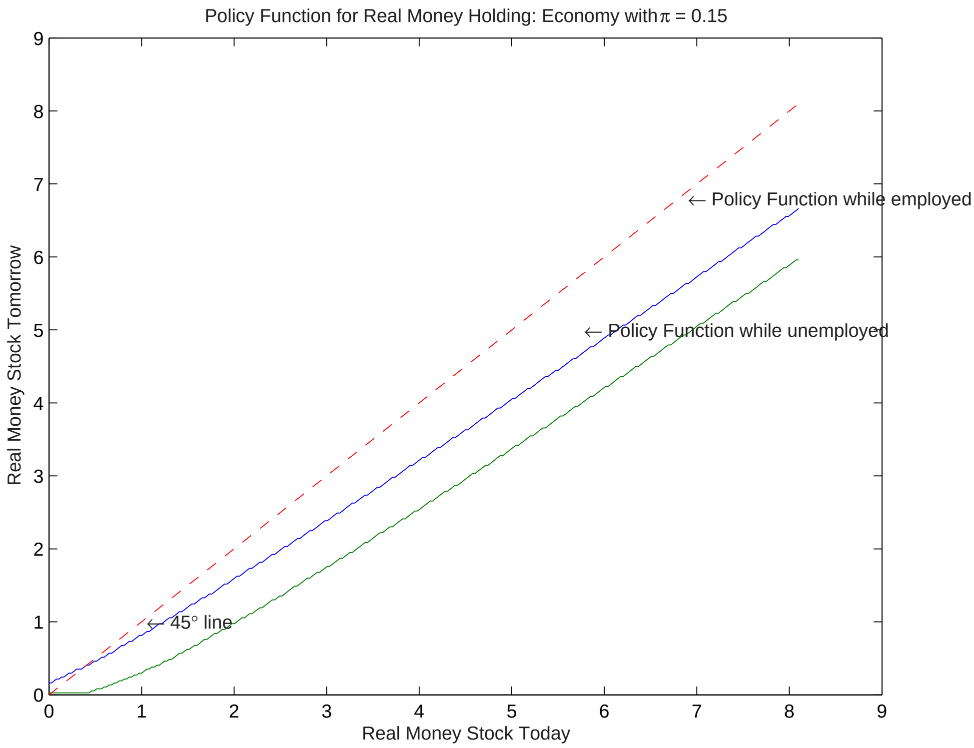

Figure 9: Stationary Distribution of Money Holdings

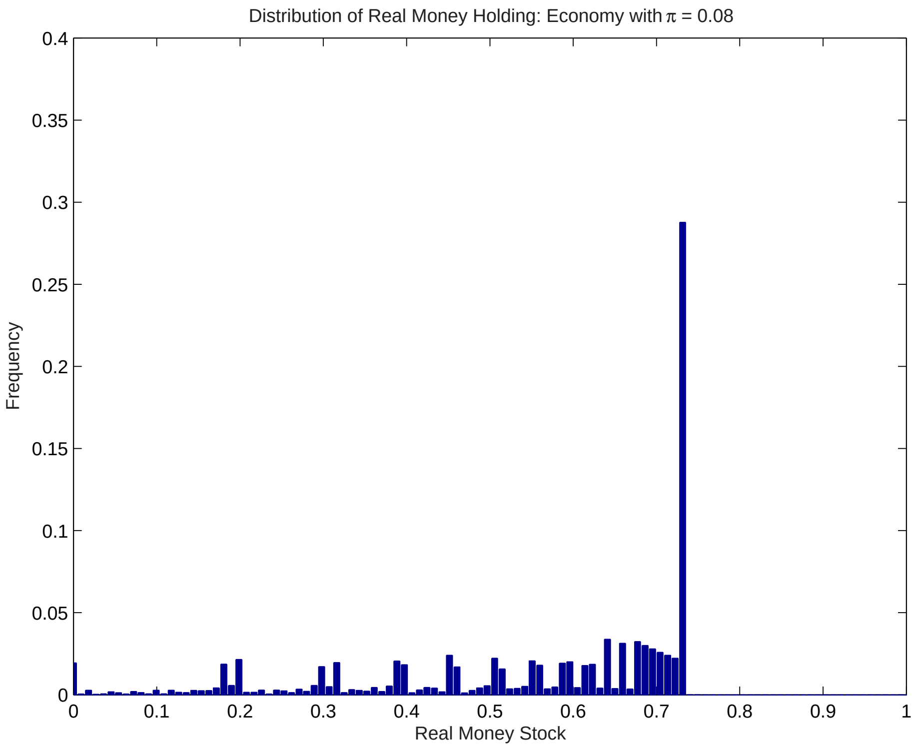

Figure 10: Stationary Distribution of Money Holdings

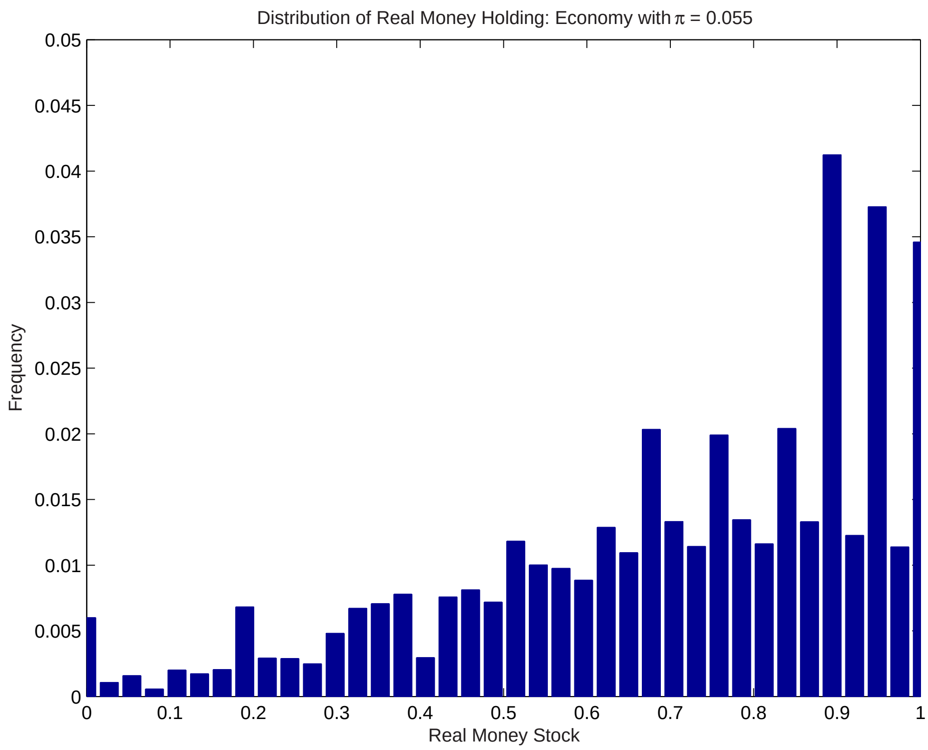

Figure 11: Policy Function with Different Employment States

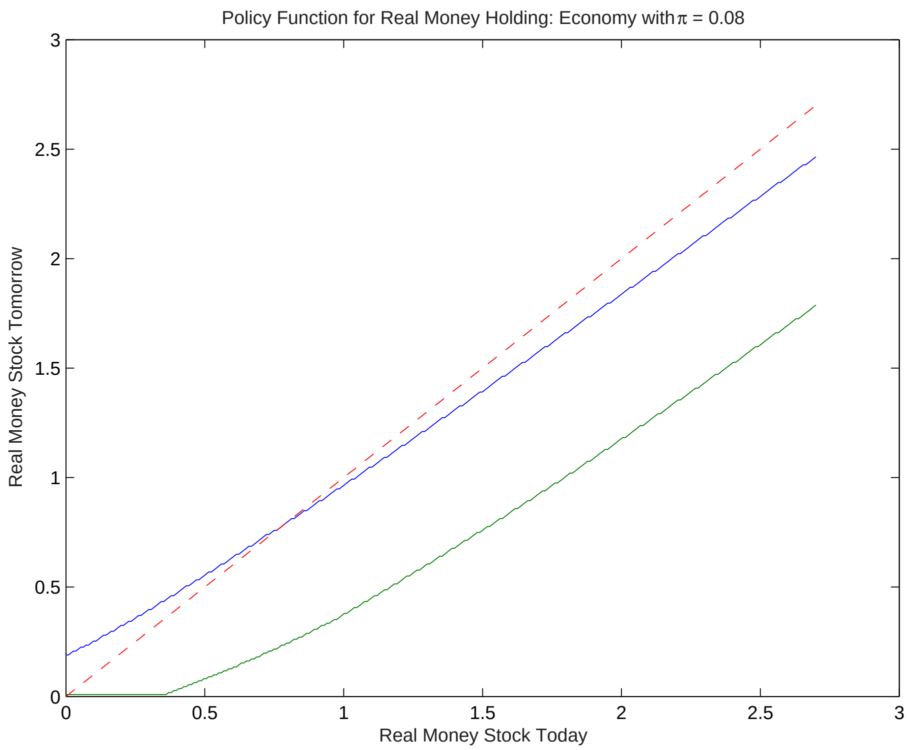

Figure 12: Policy Function with Different Employment States

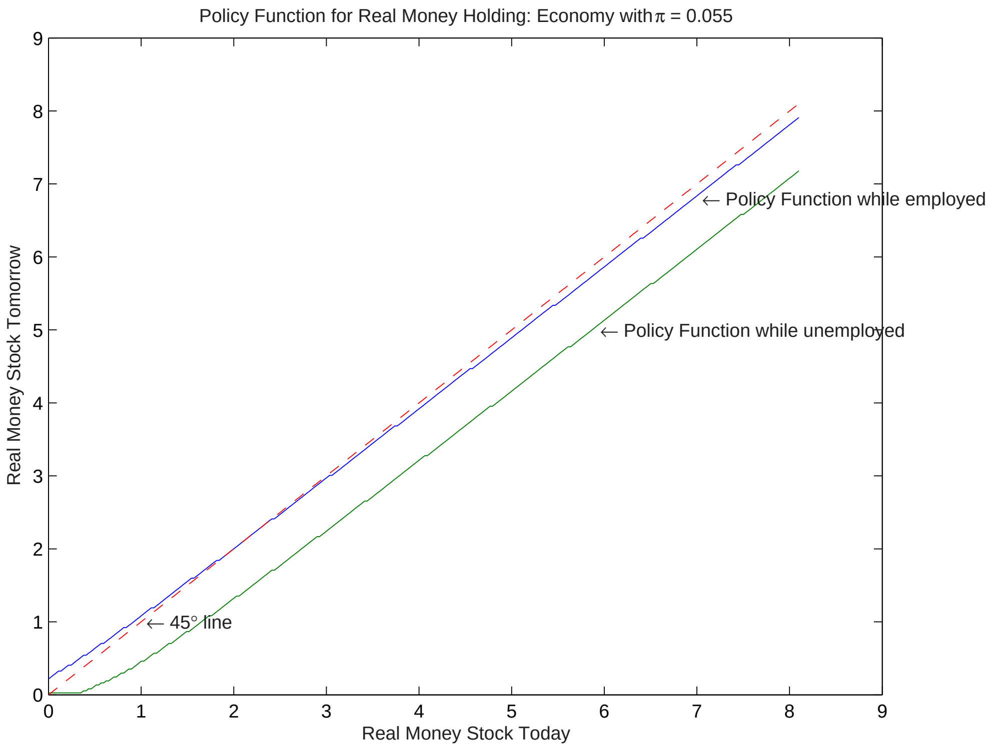

Figure 13: Policy Function with Different Employment States