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BUSINESS CYCLE FLUCTUATIONS AND THE COST OF INSURANCE IN COMPUTABLE HETEROGENEOUS AGENT ECONOMIES

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Abstract

In this paper I study the business cycle implications of alternative insurance technologies using a computable general equilibrium heterogeneous agent environment. I find that the limited monetary arrangement entails larger fluctuations in hours relative to productivity than those that obtain in an identical economy where every risk is costlessly insurable. I also find that in the monetary economy the price level displays a markedly countercyclical behavior. Finally I evaluate the welafare costs of the monetary self-insurance arrangement.

Key Words
Heterogeneous Agents; Business Cycles; Insurance Arrangements.

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Introduction

Most computable general equilibrium studies of business cycle fluctuations assume representative agents. Consequently, insurance against idiosyncratic income risks is not an issue in those economies. When labor indivisibilities result in ex-post agent heterogeneity, business cycle theorists typically assume full sets of contingent claims that imply that idiosyncratic income risks are perfectly insurable. We know that in modern industrial economies mechanisms to insure against income risks are limited. We also know that people hold liquid assets to hedge themselves against idiosyncratic income variability. Yet until recently, computational difficulties have severely limited theoretical studies of economies that include this monetary insurance feature and, as a result, we know very little about the business cycle behavior of this class of economies.

I have argued elsewhere in favor of the consumption smoothing approach to holding liquid assets (see Díaz-Giménez and Prescott [1989]). In that paper we develop the computational techniques that are needed to analyze general equilibrium structures that include a monetary insurance feature. Here, I use these techniques to explore the business cycle and welfare implications of alternative insurance technologies.

To this purpose, I study the cyclical behavior of the class of heterogeneous agent monetary economies described in Díaz-Giménez and Prescott [1989]. As a suitable term of comparison, I study the business cycle fluctuations of another class of economies where income risks are perfectly insurable. In all other respects the two classes of economies are identical. I ask whether the nature of the insurance technology assumed makes important differences in our understanding of business cycles. In particular, I study the implications of the limited monetary insurance arrangement for the yet unsettled question of the aggregate intertemporal substitutability of leisure. I also evaluate the welfare costs associated with the monetary insurance technology in terms of the additional output needed to make agents indifferent between both classes of economies.

To answer these questions I depart from the representative agent abstraction. In both classes of model economies agents' marginal productivities vary randomly over time and part of this variation is idiosyncratic. When agents work, they are paid their marginal product. Consequently agents labor income streams are variable. They also differ across agents. In the monetary economies I assume that private contracts conditional on the realizations of the individual-specific shocks are not enforceable. There is a small denomination currency-like asset issued by the government. In this paper, I am not concerned with the historical reasons for this arrangement. I simply take it for granted. Given their preferences for smooth streams of consumption and the lack of other forms of insurance, agents hold this asset to hedge themselves against their idiosyncratic income risks and they vary their asset holdings to smooth their lifetime streams of consumption. In this sense the model economy is monetary and it is part of the permanent income and of the consumption smoothing traditions.

To implement the monetary insurance arrangement the government announces explicit labor income tax rate and inflation rate policies. Each period the government exchanges currency and goods at the price implied by the inflation rate policy and it clears the market. When aggregate private purchases of goods at the policy implied prices are positive, the government sells part of the goods previously obtained from taxation. In equilibrium, of course, government consumption, which equals government tax receipts minus government sales of goods, is constrained to being non-negative.

Following Rogerson [1988] and Hansen [1985], I assume that the provision of labor services is indivisible. Agents can choose to either work forty-five hour weeks or not at all. Unlike Rogerson and Hansen, however, I do not assume a technology that allows the planner to determine randomly who is to be employed. Given that I discretize the state space and that I use numerical methods to compute the equilibrium processes, the non-convexity resulting from the indivisibility does not present any technical problems. Each period the agents decide whether or not to work in the market. Their decision depends on their current asset holdings and on the current market value of their time which, in turn, depends upon the realization of their partly idiosyncratic productivity shocks.

At each point in time, therefore, agents are heterogeneous with respect to the market value of their time and, in the monetary economies, with respect to their asset positions. Ex-post, they also differ in their consumption and employment status. These cross-sectional differences result endogenously from the agents' optimal responses to the different histories of their individual shocks which condition their saving and employment decisions.

Including capital in this class of economies makes the computation costs unmanageable. I therefore abstract from capital accumulation in this study. Consequently, agents can only smooth consumption by varying their holdings of liquid assets. The inflation tax levied on these assets increases the cost of future consumption in terms of current consumption. The desire to accumulate liquid assets is one of the reasons that accounts for large fluctuations in aggregate hours in response to small transitory changes in average labor compensation and drives some of the other business cycle properties of these models.

Since there is no capital accumulation in this class of economies it is difficult to compare my results with those of previous computable general equilibrium studies of the business cycle. To provide a more suitable term of comparison, I analyze the business cycle behavior of a perfect insurance economy that also abstracts from capital accumulation. In the perfect insurance economy there are no limitations on the set of contingent claims available to agents and all income risks are costlessly insurable. In all other respects both economies are identical. In particular they are both subject to the same histories of shocks and they have the same labor income tax rates and sequences of government expenditures. In the perfect insurance economy lump-sum taxes generate the seignorage revenues of the monetary economy and enable the government to satisfy its budget. In Sections 1 and 2 I describe the monetary and the perfect insurance economies. To determine the values of the model parameters I calibrate both structures to U.S. time series and micro data. In Section 3 I discuss my calibration choices. I then simulate the model economies and in Section 4 I report the cyclical behavior.

The monetary insurance arrangement, however, implies that the intratemporal allocations of consumption and leisure across the different agent types are suboptimal. For policy purposes it would be interesting to obtain an estimate of the welfare costs arising from the existence of uninsurable risks. To evaluate these costs, in Section 5 I calculate the average level of lump-sum taxes that makes agents indifferent between the monetary economy and perfect insurance economy. Section 6 concludes the paper.

Section 1. The Imperfect Insurance Monetary Economies

Agents

There is a continuum of agents with total measure one. The agents order their random streams of consumption and leisure according to:

$$E \sum_{t=0}^{\infty} \beta^t u(c_t , \tau - n_t) \tag{1}$$

where $c_t \geq 0$ is a perishable consumption good and u is concave and increasing in both arguments. Parameter τ is the total endowment of productive time and n_t is the amount of time allocated to market activities. Consequently, $\tau - n_t$ is time allocated to household production. Here it is simply called leisure.

Agents are heterogeneous with respect to their asset holdings and with respect to the realizations of the individual-specific productivity shock. At each point in time the measure of agents of type (a,s) is $x_t(a,s)$. The initial measure of agent types is x_0.

Information

There is an exogenous economy-wide stochastic process $\{z_t\}$. This process is a Markov chain with transition probabilities,

$$\pi(z,z') = \Pr\{z_{t+1} = z' \mid z_t = z\}$$
$$\text{for } z, z' \in Z = \{1,2,\ldots,n_z\}$$

There are identically distributed individual specific stochastic processes $\{s_t\}$. Conditional on $\{z_t\}$, the $\{s_t\}$ processes are independent across individuals and follow a finite state Markov chain. The conditional transition probabilities are:

$$\pi(s,s' \mid z') = \Pr\{s_{t+1} = s' \mid s_t = s,\ z_{t+1} = z'\}$$
$$\text{for } s, s' \in S = \{1,2,\ldots n_s\} \text{ and } z' \in Z$$

The joint processes on (s,z) are therefore Markov chains with $n = n_s n_z$ states. Their transition probabilities are:

$$\pi\left[(s',z') \mid (s,z)\right] = \Pr\{z_{t+1} = z' \mid z_t = z\}\Pr\{s_{t+1} = s' \mid s_t = s,\ z_{t+1} = z'\}$$

Agents know the laws of motion of both $\{s_t\}$ and $\{z_t\}$. At the beginning of each period they observe the realizations of both stochastic processes. Trade ensues.

Technologies

If $s_t = s$ and $z_t = z$, the agent's date t production possibility set is determined by:

$$0 \le y_t \le w(s,z)n_t$$

where y_t is the agent's pre-tax output of the date t consumption good, and w(s,z) is a technology parameter. When agentes choose to work, they are paid their marginal product. Parameter w(s,z) therefore equals the individual real wage.

Following Rogerson [1988] and Hansen [1985], I assume a labor indivisibility. Hours of labor services provided, n_t, are constrained to belong to the set {0, 1}. Zero corresponds to not being employed and one corresponds to being employed. Unlike them, however, I do not assume a technology that allows the planner to determine randomly who is to be employed. Agents either choose to work or they choose not to. When they choose to work, they can dedicate part of their earnings to insure themselves against future income variability by accumulating liquid assets. When they choose not to work, they use their previously accumulated savings to finance their consumption.

Monetary Arrangements

Individual real wages vary randomly over time. As we have just seen, part of this variation is idiosyncratic. The real wage variations interacting with the agents' employment decisions give rise to income variations. Private contracts conditional on the realizations of the individual-specific productivity shocks are not enforceable in this class of economies. Agents therefore have no access to private technologies to hedge themselves against income risks. Their preferences for smooth streams consumption induce them to hold liquid assets. In this environment there is only one such asset. It is issued by the government in small denominations and, since it is constrained to being non-negative, I call it currency. Each period the government exchanges goods for currency at the policy determined price p_t and it clears the market. When aggregate private purchases of goods turn out to be positive at this policy implied price, the government sells part of the goods previously obtained from taxation. The market clearing price is chosen to satisfy $p_t = p_{t-1}\, e(z_t)$, where $e(z_t)$ is the inflation rate. The inflation rate policy, $e(z_t)$, and the labor income tax rate policy, $\theta(z_t)$, are restricted to being a function of the exogenous component of the economy-wide state only. This restriction was dictated by computational considerations.[1]

Agents can therefore hold integer amounts of small denomination currency

$$a \in A = \{0,1,2,\dots,n_a\}$$

States

The state of an individual is the pair (a,s). Variable a is its endogenous component and it denotes the real value of an individual's beginning of period assets in terms of the previous date price level. Computational considerations led me to this particular choice of units. Variable s is the exogenous component of the individual state and it denotes the individual-specific productivity shock. The measure of agents of type (a,s) is x(a,s). We let x denote the corresponding measure. The economy-wide state is the pair (x,z). The measure of agent types, x, is its endogenous component and the economy-wide productivity shock, z, is its exogenous component.

Controls

Each household chooses consumption $c(a_t,s_t,z_t)$, employment $n(a_t,s_t,z_t)$, and real currency balances $a'(a_t,s_t,z_t)$. Government policy determines the labor income tax rate, $\theta(z_t)$, and the inflation rate, $e(z_t)$. The government either buys goods or sells part of the goods obtained from taxation and clears the market at the policy implied prices. The quantity of goods consumed by the government is $g(x_t,z_t)$. It is equal to tax revenues plus government purchases of goods and, in equilibrium, it is constrained to being non-negative. Government consumption does not increase the utility of private agents.

Individuals' Optimization Problem

The individuals' dynamic program is

$$v(a,s,z) = \max_{c,a',n} \left\{u(c,\tau\text{-}n) + \beta \sum_{s',z'} v(a',s',z')\ \pi\ \left[(s',z') \mid (s,z)\right]\right\}$$

subject to the budget constraint

$$c + a' \leq \frac{a}{e(z)} + nw(s,z)\left[1-\theta(z)\right]$$

and to

$$c \geq 0,\ a' \in \{0,1,...,n_a\} \text{ and } n \in \{0,1\}$$

Definition of Equilibrium

An equilibrium for this class of economies is a government policy $\left[e(z), \theta(z)\right]$, a household policy $\left[c(a,s,z), a'(a,s,z), n(a,s,z)\right]$ and a law of motion for the measure of agent types $x' = f_{a's'}(x,z,z')$ such that:

i. Given the process on prices, the household policy solves the individual optimization program described above.

ii. The implied g sequence is non-negative:

$$\sum_{a,s} x_{as}\left[n(a,s,z)w(s,z) - c(a,s,z)\right] = g(x,z) \geq 0$$

for all (x,z)

iii. Individual and aggregate behavior are mutually consistent

$$f_{a's'}(x,z,z') = \sum_{a,s \in \phi(a',z)} x(a,s)\pi(s' \mid s,z')$$

$$\text{where } \phi(a',z) = \{(a,s)\text{: } a' = a'(a,s,z)\}$$

Given that the agent's problem is a finite state, discounted dynamic program, an optimal stationary Markov plan always exists.

Computation

The following computational procedure determines whether an equilibrium exists. The first step of is to obtain the households' optimal policy rules given the government policy and the informational components of the individual and economy-wide states. The second step is to use the households' optimal policy rules and the transitions on the stochastic processes to obtain f(x,z,z'). The third step is to determine g(x,z) residually from the market clearing condition. If g(x,z) turns out to be non-negative for every possible realization of the joint stochastic processes, an equilibrium exists for the given policy $[e(z), \theta(z)]$. If this is not the case, no equilibrium exists for that policy.

Until recently, computational difficulties have severely limited the study of this class of monetary economies. The linear-quadratic approach that has proved to be so useful in other quantitative theoretical studies cannot be used here. This approach involves approximating the economies about their steady states once the random variables are set equal to their unconditional means. If agents were to receive their average income each period, the consumption smoothing role of liquid assets disappears. The linear-quadratic approach would therefore involve approximating the economies around zero asset holdings. This would afford a rather poor approximation. To bypass this problem, I follow Imrohoroglu [1988] and [1989]. I discretize the state space and I use numerical methods and the supercomputer to calculate the equilibrium processes for the model economies. Given the relatively large size of the state space, the numerical algorithm combines value and policy iterations to keep the computation costs within reasonable limits. Fully documented version of the FORTRAN programs used to compute the equilibrium processes and to simulate the behavior of the economies are available upon request from the author.

Section 2. The Perfect Insurance Economies

The perfect insurance economies differ from the monetary economies in that private contracts conditional on the realization of the individual-specific shocks can be enforced. Consequently, agents can completely insure themselves against all risks. This feature leaves no role for a currency-like asset. In every other respect both classes of economies are identical. Specifically they have the same labor income tax policies, the same sequences of government consumption and the same histories of shocks. In the perfect insurance economies, lump-sum taxes generate the seignorage revenues of the monetary economies and enable the geovernment to satisfy its budget.

Agents

There is a continuum of agents with total measure one. As they did in the monetary economies, agents order their random streams of consumption and leisure according to (1). Agents are heterogeneous with respect to the realizations of the individual-specific shock, s. At each point in time the measure of agents of type s is $\bar{x}_t(s)$ and the initial measure of agent types is $\bar{x}_0$. To make both classes of economies comparable I require that, for each s,

$$\bar{x}_0(s) = \sum_{a \in A} x_0(a,s)$$

Information and Technologies

The properties and realizations of the stochastic processes, the timing of the information and the nature of the production technologies are identical to the corresponding ones of the monetary economies described above.

Insurance Arrangements

In the perfect insurance economies, private contracts conditional on the realizations of the individual-specific shock can be enforced. The concavity of the utility function implies that the agents are risk averse. Consequently, before the individual-specific shock is realized at the beginning of each period, the agents trade contracts that equate the utility of workers and non-workers regardless of their individual marginal productivities. This class of contracts can be trivially shown to be optimal. In the perfect insurance economies, therefore, agents do not value currency. The enforceability of contracts and the exogenous nature of the lump-sum taxation reduce the agents' dynamic problem to a sequence of static social planner problems which I describe below.

States

The state of an individual is the realization of its productivity process, s. The economy-wide state is the pair ($\bar{x}$, z). The measure of agent types, $\bar{x}$, is its endogenous component and the economy-wide productivity shock, z, is its exogenous component.

Controls

Each period, for each agent type s, the households trade contracts that determine the measure of agens who work in the market, $\bar{n}(s)$, and the consumption levels for workers, c_1, and for non-workers, c_0.

Given the sequence of government expenditures, $\{g_t\}$, the labor income tax rate policy, $\theta(z_t)$, and the agents' optimal choices, the government determines its sequence of lump-sum taxes, $\{T_t\}$, that enables it to satisfy its budget.

The Agents' Optimization Problem

Given the level of lump-sum taxes, T, the measure of agent types, $\bar{x}$, and the realization of the economy-wide process, z, at the beginning of each period, the agents trade contracts that guarantee them the allocations of leisure and consumption that solve the following social planner's problem:

$$\max_{c_1, c_0, \bar{n}(s)} \sum_s \bar{n}(s) u(c_1, \tau - 1) + \sum_s \left[\bar{x}(s) - \bar{n}(s)\right] u(c_s, \tau)$$

s.t.

$$\sum_s \bar{n}(s)\, c_1 + \sum_s \left[\bar{x}(s) - \bar{n}(s)\right] c_0 \leq \sum_s \bar{n}(s) w(s,z)\left[1 - \theta(z)\right] - T$$

$$\bar{n}(s) \leq \bar{x}(s) \qquad \text{for } s=1, 2, \ldots, n_s$$

$$c_0, c_1, \bar{n}(s) \geq 0 \qquad \text{for } s=1, 2, \ldots, n_s$$

Definition of Equilibrium

Given the initial measure of agent types x_0, the labor income tax rate policy, $\theta(z_t)$, the sequence of government expenditures, $\{g_t\}$, and the law of motion for the measure of agent types, $\bar{x}' = f_s(\bar{x}, z, z')$ implied by the joint stochastic processes, an equilibrium for this economy is a household policy, $\left\{c_{1t}, c_{0t}, \bar{n}(s)\right\}_{t=0}^{\infty}$, and a government policy, $\left\{T_t\right\}_{t=0}^{\infty}$ such that:

i. Given $\theta(z)$, T and the realization of the economy-wide process, z, each period the households' policy solves the optimization problem described above.

ii. The government budget constraint is satisfied each period, i.e. $\forall t \geq 0$:

$$g_t = \theta(z_t) \sum_s \bar{n}_t(s) w(s,z_t) + T_t \tag{1}$$

Computation

Specializing the agents' optimization problem to the case where $s \in \{1,2\}$, and keeping the labor income tax rates time invariant, the Kuhn-Tucker conditions for this problem collapse to:

$$c_1: \quad u_1(c_1, \tau - l) - \lambda_1 \leq 0 \qquad (= 0 \text{ if } c_1 > 0) \tag{2}$$

$$c_0: \quad u_1(c_0, \tau) - \lambda_1 \leq 0 \qquad (= 0 \text{ if } c_0 > 0) \tag{3}$$

$$n_1: \quad u(c_1, \tau - l) - u(c_0, \tau) + \lambda_1 \left[w(1,z)(1-\theta) - c_1 + c_0 \right] - \lambda_2 \leq 0$$
$$(= 0 \text{ if } n_1 > 0) \tag{4}$$

$$n_2: \quad u(c_1, \tau - l) - u(c_0, \tau) + \lambda_1 \left[w(2,z)(1-\theta) - c_1 + c_0 \right] - \lambda_3 \leq 0$$
$$(= 0 \text{ if } n_1 > 0) \tag{5}$$

$$\lambda_1: \quad \left[\bar{n}(1) + \bar{n}(2) \right] c_1 + \left[1 - \bar{n}(1) - \bar{n}(2) \right] c_0 -$$
$$\left[\bar{n}(1) w(1,z) + \bar{n}(2) w(2,z) \right] (1-\theta) + T \leq 0 \qquad (= 0 \text{ if } \lambda_1 > 0) \tag{6}$$

$$\lambda_2: \quad \bar{n}(1) - \bar{x}(1) \leq 0 \qquad (= 0 \text{ if } \lambda_2 > 0) \tag{7}$$

$$\lambda_3: \quad \bar{n}(2) - \bar{x}(2) \leq 0 \qquad (= 0 \text{ if } \lambda_3 > 0) \tag{8}$$

$$\bar{n}(1), \bar{n}(2), c_1, c_0, \lambda_1, \lambda_2, \lambda_3 \geq 0 \tag{9}$$

Prescott and Townsend [1984] show that the Kuhn-Tucker conditions (2)–(8) are sufficient for a maximum and that the solution is unique. Further, the specific form of the utility function that I discuss below guarantees that the optimal consumption levels, (c_0^o, c_1^o), are non-negative for every realization of the joint process (s,z).

To compute the equilibrium I use the following solution algorithm where superscript ^{o} indicates optimal levels and the superscript * indicates equilibrium levels:

i. As long as there are highly productive workers available, it is optimal for them to be the first ones to work. I therefore start by supposing that $\bar{n}^o(2) = 0$. Then, without loss of generality, I let $\lambda_2^o = 0$. Substituting λ_2^o into (4), and solving (2), (3) and (4) at equality, I obtain c_1^o, c_0^o and λ_1^o. Given $\bar{n}^o(2)$, c_1^o, c_0^o and g, from (6) at equality and (1), I find $\bar{n}^o(1)$ and T^o.

ii. If $\bar{n}^o(1,z) \leq 0$, then the solution is, trivially:
$\bar{n}^*(1) = 0, \bar{n}^*(2) = 0, c_1^* = 0, c_0^* = -g$ and $T^* = g$.

iii. If $0 < \bar{n}^o(1) \leq \bar{x}(1)$, then the solution is:
$\bar{n}^*(1) = \bar{n}^o(1)$, $\bar{n}^*(2) = 0, c_1^* = c_1^o, c_0^* = c_0^o$ and $T^* = T^o$.

iv. If $\bar{n}^o(1) > \bar{x}(1)$, then I let $\bar{n}^*(1) = \bar{x}(1)$ and $\lambda_3^o = 0$. Substituting λ_3^o into (5), and solving (2) and (3) and (5) at equality, I obtain c_1^o, c_0^o and λ_1^o. Given $\bar{n}^*(1)$, c_1^o, c_0^o and g, from (6) at equality and (1), I find $\bar{n}^o(2)$ and T^o.

v. If $\bar{n}^o(2) \leq 0$, then the solution is:
$\bar{n}^*(1) = \bar{x}(1)$, $\bar{n}^*(2) = 0$ and the $(c_1^o, c_0^o, T^o, \lambda_1^o)$ resulting from substituting these values into (1) and (6) and solving the system formed by (1) and (2) and (3) and (6) at equality.

vi. If $0 < \bar{n}^o(2) \leq \bar{x}(2)$, then the solution is:
$\bar{n}^*(1) = \bar{x}(1), \bar{n}^*(2) = \bar{n}^o(2), c_1^* = c_1^o, c_0^* = c_0^o$ and $T^* = T^o$.

vii. If $\bar{n}^o(2) > \bar{x}(2)$, then the solution is:

$\bar{n}^*(1) = \bar{x}(1)$, $\bar{n}^*(2) = \bar{x}(2)$ and the $(c_1^\circ, c_0^\circ, T^\circ, \lambda_1^\circ)$ resulting from from substituting these values into (1) and (6) and solving the system formed by (1) and (2) and (3) and (6) at equality.

Section 3. Calibration

Following the general equilibrium computable business cycle tradition, I use U.S. time series and micro data to determine the value of most of the parameters of the model economies. Whenever possible, I choose time series data that are independent of the business cycle phenomena under consideration. I calibrate the remaining parameters so that the deviations of logged output from their trend are close to the corresponding ones for the U.S. economy in the 1954-85 period. In constructing the model economy aggregates, I try to replicate the methods used to obtain the corresponding U.S. economy series. Appendix 1 contains the definitions of the model aggregates and of the quarterly time series of interest. I discuss my parameter choices below.

Time Period

Most of the relevant U.S. time series consist of annually quoted quarterly data. A quarter of a year seems too long a period for people to commit themselves to fixed holdings of small denomination assets. It therefore seemed reasonable to choose a shorter model period. My choice of an eighth of a year as the model period was based on two reasons: it allows for some temporal aggregation and, at the same time, it keeps the computation costs within reasonable limits.

Preferences

Following Kydland and Prescott (1982) and the business cycle tradition, I choose the functional form for U to be:

$$U(c_t, \tau-n_t) = (1-\sigma)^{-1} \{[c_t^{\alpha} (\tau-n_t)^{1-\alpha}]^{1-\sigma} - 1\}$$

where τ-n is leisure.

This functional form implies a unit contemporaneous elasticity of substitution between consumption and leisure. This fact is consistent with the U.S. economy observation that, secularly, per capita leisure has shown no significant trend while real income has increased continuously. I choose preference parameters β=0.995 and α=0.33. These parameter values imply an annual subjective time discount rate of 4 percent, and a share of leisure of approximately 2/3. These values for the time discount rate and for the share of leisure match with observations from national income product accounts on the real net return on capital, and on the average fraction of productive time that households allocate to the market. A share of leisure of 2/3 implies an intertemporal elasticity substitution of 2 for this variable. The available microeconomic evidence on the actual value of this parameter is far from conclusive. Hall [1980] reviews this evidence. Based on the studies of the PSID reported by Heckman and Macurdy [1977] and Macurdy [1978], he concludes that 2 is a reasonable value for this parameter. Moreover it is the value typically used by the business cycle tradition.

For the relative coefficient of risk aversion, σ, I choose a value of 1.5. Again, this value is commonly used in applied general equilibrium exercises in public finance and in business cycle theory. My choice of τ reflects the fact that, on average, when people choose to work they allocate 45 percent of their time to market activities. This corresponds to a work-week, including commuting time, of approximately 45 hours. Parameter τ is, therefore, the reciprocal of 0.45, i.e., τ=1.22.

Transition on the Economy-wide Exogenous Process.

The aggregate process can take two values, $z \in \{1,2\}$. State z=1 represents good times and state z=2 represents bad times. The transition probabilities on the aggregate process determine the average duration of each of the shocks. In the U.S., business cycles last on average for about four years (see, for example, Delong and Summers [1977]). Consequently the average duration of good and bad times is of about two years which correspond to sixteen model periods. The expected duration of a state is the reciprocal of $1-\pi(z,z)$ where $\pi(z,z)$ is the probability of state z occurring again the following period. The transition matrix for the aggregate shock that satisfies these conditions is the following:

	$z' = 1$	$z' = 2$
$z = 1$	0.9375	0.0625
$z = 2$	0.0625	0.9375

Transition on the Individual-Specific Exogenous Process

The individual-specific productivity shock can take two possible values, $s \in \{1,2\}$. State s=1 represents periods when an agent is highly productive and state s=2 represents periods when an agent receives a low productivity shock. This would be the case, for instance, of a qualified electrician who can only find a job as a janitor. The transition probabilities are chosen so that, on average, 92 percent of the time agents experience the high productivity shock and the remaining 8 percent of the time they experience the low productivity shock. I also require the expected duration of the low productivity shock to be of two model periods, or a quarter of a year. These values roughly match the average U.S. employment rate and the expected duration of unemployment in U.S. business cycles. For the model economy, the transition matrix on the individual-specific process that satisfies these requirements, independently of the realization of the aggregate process, is the following:

	$s' = 1$	$s' = 2$
$s = 1$	0.9565	0.0435

s = 2	0.5000	0.5000

Technologies

The technology parameters for the model economies are denoted w(s,z). I calibrate them so that, given the transitions on the exogenous processes, the variations of the model aggregate output series match those of U.S. real GNP. For the model economies, the productivity parameters are the following:

w(1,1)	w(1,2)	w(2,1)	w (2,2)
1.009	0.991	0.33297	0 .32703

These choices imply a 2.34% difference between the market value of the agents' time in good and in bad times for both realizations of the individual-specific process. The ratio of the marginal productivity parameters for high and low productivity agents is chosen to be 3. This number is close to the ratio between the average hourly wage in manufacturing and the minimum hourly wage in the U.S.. With these calibration choices I am assuming that there are always minimum wage openings for anyone who wants them. As can be seen from Table 4.1 these calibration choices result in a percentage standard deviation of the filtered deviations of logged output that is only 2 percent larger than the corresponding one for the U.S. economy.

Monetary and Fiscal Policy Parameters

The government determines the labor income tax rate and the inflation rate policies. I choose a time invariant labor income tax rate of 0.25 and an average inflation rate of 4%. These values are rough approximations to U.S. average tax rates and to the average percentage rate of change in the U.S. GNP deflator for the period under consideration.

The inflation rate varies procyclically. It is 3 percent p.a. in bad times and 5 percent p.a. in good times.

I use a grid of 400 points in the asset space. This results in a currency unit of 0.0125 which is 0.18 percent of per capita yearly income of the calibrated model economy. If we take U.S. per capita income to be $20,000, this currency unit would approximately correspond to having $36 bills. Asset spaces with finer grids increase the computational costs and do not result in any significant differences in the cyclical behavior of the model economies. The maximum value of total asset holdings is 5. This number is sufficiently large so that the constraint is never binding in equilibrium.

Finally, government purchases of goods are equal to the net sales of the private sector, and government consumption equals tax receipts plus government purchases. Government consumption leaves less goods to be consumed by the private sector. Therefore, in order to make both economies comparable, they must be subject to the same sequence of government consumptions. In the perfect insurance economy, lump-sum taxes generate the seignorage revenues of the monetary economy and enable the government to satisfy its budget.

Section 4. The Business Cycle Behavior of the Economies

Once the monetary economy has been fully specified, I compute the agents' optimal decision rules following the method outlined in Section 1. I then simulate the model economy twenty thousand times to purge away the initial conditions. Next, I compute the model economy aggregates for twenty one samples of two hundred and sixty eighthly observations, which I then aggregate into one hundred and thirty quarters. After each eighthly sample is drawn, I simulate the economy two hundred times to make the calculations independent across samples.

In studying the business cycle properties of the model aggregate series I use Lucas [1977] definition of business cycles as "movements about trend in gross national product". For an operational definition of "trend" I decompose the aggregate series into their trend and deviation components following the methods first outlined in Kydland and Prescott [1982] and later discussed at greater length in Prescott [1986] and Kydland and Prescott [1990]. I therefore log every series except those containing ratios or rates and I filter them using the Hodrick and Prescott filter with a value of λ=1600. Finally, in selecting which statistics to report I follow the guidance of neoclassical growth theory and of Kydland and Prescott [1990]. I therefore report the size of the fluctuations and the sign and the size of the phase-shift of the comovement of the aggregate variables and real output. Hence Tables 4.1, 4.2 and 4.3 contain the standard deviations and the correlations of leads and lags of the relevant aggragate series for, respecrtively, the U.S. economy, the monetary economy and for the perfect insurance economy. I find the following:

i. The Size of the Fluctuations

The amplitude of the cycles

As can be seen from comparing the first columns of Tables 1 and 2, the amplitude of the fluctuations of the monetary economy aggregates is surprisingly close to that of the corresponding series of the U.S. economy once they have been judiciously chosen. This result indicates that the calibration exercise has been successful and can be interpreted to suggest that the monetary insurance mechanism is a reasonably close substitute for capital accumulation as a way of transferring consumption to the future. However given that I abstract from capital accumulation in the model economies, the comparison of Tables 2 and 3 is, by far, the most meaningful.

We can see that output fluctuations are significantly larger in the monetary economy than in the complete insurance economy. (17% in the experiment reported). In the monetary economy agents accumulate liquid assets to improve their lifetime allocations of consumption and leisure while the perfect insurance arrangement allows for optimal allocations of consumption and leisure across agents each period. I find that the individual intertemporal substitution mechanism entails larger fluctuations of the main economic series than the collective contemporaneous one. I conducted similar experiments with different inflation rate policies[2] and the above result proved to be robust to those changes.

Government Consumption

I find that implementing the monetary mechanism entails large variations in government consumption. These variations increase significantly (they are 53% larger) in economies were inflation rates are kept time invariant when compared with those in which inflation is allowed to follow the cycle. These additional fluctuations in government consumption are needed to absorb the productivity variations while keeping the rates of change of prices constant. As we have seen, the monetary economies agents vary their holdings of liquid assets to smooth their life-streams of consumption. Once the aggregate consumption and savings decision is made, government consumption is determined residually to clear the markets. I find that the implementation of this mechanism entails large fluctuations in government consumption. In fact, I find that it is hard to reduce the size of government consumption fluctuations under simple specifications of fiscal and monetary policy.

Hours and Productivity

Accounting for the relative fluctuations of hours and productivity or real wages is one of the major challenges faced by any model of business cycles. In the U.S. economy during the 1954-85 period the ratio of the deviations in hours as measured by the household survey to real compensation per hour in the business sector was 1.63. For the basic divisible labor growth structure described in Hansen [1985] the value of this ratio is 1.03. This number is clearly too small. When Hansen modifies the basic growth structure to include Rogerson [1988] labor indivisibilities, he obtains a value of 2.7 for this ratio.

Hansen assumes full sets of contingent claims and a technology that enables the planner to determine randomly who is to be employed each period. As we have seen, the heterogeneous agent monetary construct does not include either of these features. Unfortunately it also abstracts from capital accumulation. Its ratios, therefore, can only be meaningfully compared to those of the perfect insurance economy described in this paper. I find that when agents self-insure against income variability by holding liquid assets the ratio of the fluctuations in hours and real wages is 1.58. In the perfect insurance economy this number is 1.27. The limited monetary insurance abstraction, therefore, results in a move in the right direction. I have no reasons to believe that this finding would be overturned if capital were to be included in these structures. Until someone comes up with a way to solve this non-trivial problem, this last statement, of course, is nothing more than an informed conjecture.

ii. The sign, size and phase-shift of the comovements of the variables and output

The x(t±j) column of Tables 4.1, 4.2 and 4.3 contain the correlation coefficients of the cyclical deviations of each series shifted forward or backwards j periods and the deviations of period t real output. The largest number in each row indicates the maximum degree of correlation and therefore, the phase shift of the series and the output cycle.

Contemporaneous Correlations

The first striking feature of the monetary economy is the high degree of contemporaneous correlation of the consumption, government consumption, hours, wages and employment series. The perfect insurance economy reproduces this property to a somewhat smaller extent. An explanation for this feature is that it is only productivity variations that drive the cycle.

Dampened fluctuations

Secondly, abstracting from capital accumulation has important dampening effects in the propagation of the productivity shocks. When comparing the monetary and the perfect insurance economies, I find that the limited monetary insurance arrangement further compuounds this dampening effect.

Procyclical Government

Third, government consumption is highly procyclical and displays no phase shift. Several reasons justify this result. First, it must be kept in mind that I abstract from government debt and, therefore, the government is foreced to satisfying its budget each period. Second, labor income tax receipts are the main component of government income and we have already seen that the provision of labor services is highly procyclical. Finally, under the monetary insurance arrangement, agents save in good times and dissave in bad times to smooth their consumption. Consequently, private net sales of goods and, therefore, the purcahses and consumption of the government follow the cycle.

Countercylclical prices

In their 1990 paper, Kydland and Prescott document the common belief on the procyclical behavior of the price level. They next argue that, in the U.S., this was indeed the case in the period between the wars. Finally they show that, since the Korean war, in the U.S. the behavior of the price level, whether measuered by the GNP deflator or by the consumer price index has been clearly countercylical and that prices lead the opposite phase of the GNP cycle by approximately two quarters. A remarkable and unexpected feature of the heterogeneous agent monetary construct is that it reproduces exactly this same property.

Section 5. Welfare Comparisons

In this section I study the welfare properties of the consumption smoothing monetary arrangement. When compared with their colleagues of economies where contracts conditional on the realizations of the individual-specific shock can be enforced, the agents of the monetary economies incur into two types of welfare losses: those that arise from the presence of uninsurable risks that make the allocation of consumption and leisure across agents each period suboptimal, and those that arise from the inflation tax that makes the intertemporal substitution of consumption costly.

Computational considerations lead me to choose the following method to carry out the welfare comparisons: Average utility in the perfect insurance economy is a function of the level of lump-sum taxes, T_t, of the labor income tax rate, θ_t , of the marginal distribution of agent types $\bar{x}_t(s)$, and of the realization of the economy-wide shock, z_t. Throughout these welfare comparison experiments I keep θ_t time invariant and equal to 0.25. The sequence of economy-wide shocks, $\{z_t\}$, is identical in both structures, and the distribution of agent types in the perfect insurance economy is the marginal distribution of agent types of the monetary economy as indexed by the realizations of the individual-specific shock i.e.,

$$\bar{x}_t(s) = \sum_{a \in A} x_t(a,s),$$

where set A denotes the asset space. Given $\{\theta, z_t, x_t\}$, average utility in the perfect insurance economy only depends on the level of lump-taxes, T. Higher levels of T imply lower levels of average utility. To calculate the welfare differences between both economies I use standard independent sampling theory to construct 99 percent confidence intervals for the average additional amount of lump-taxes, ε, that is needed to make agents indifferent between both economies.

The method I use to find this interval is the following: I choose a value for $\varepsilon>0$. I then draw 21 samples of 260 observations for the monetary economy. For each sample point, I obtain the $x_t(a,s)$, the equilibrium level of government consumption, g_t, and the average utility for the monetary economy, u_t^m. I then use x_t (.,s), g_t and z_t to compute the average utility of the perfect insurance economy, $u_t^p(e)$. For each sample I compute the sample average difference in utilities, $\bar{d}^s$, where

$$\bar{d}^s(\varepsilon) = \frac{1}{N} \sum_{n=1}^{N} (u_n^p(\varepsilon) - u_n^m)$$

and N is the size of the sample.

After each sample is drawn, I simulate the monetary economy five hundred times to make the calculations independent across samples and I then draw another sample. When the 21 samples are drawn, I compute the estimates of the first and second moments of the sampling distribution:

$$\bar{d}(\varepsilon) = \frac{1}{S} \sum_{s=1}^{S} \bar{d}^s(\varepsilon)$$

and

$$S_{\bar{d}}(\varepsilon) = \sqrt{\frac{1}{S-1} [\bar{d}^s(\varepsilon) - \bar{d}(\varepsilon)]^2}$$

where S is the number of samples.

A 99 percent confidence interval of $\bar{d}(\varepsilon)$ is, then, $\bar{d}(\varepsilon) \pm 2S_{\bar{d}}(\varepsilon)$. I repeat this procedure for different values of ε. I stop when I obtain two intervals that are entirely at either side of zero but as close to zero as seems computationally reasonable. The 99 percent confidence interval for the average lump-sum tax that makes agents indifferent between both economies is determined by the segment whose end points are the intersections with the ε-axis of the lines determined by the end points of both intervals (see Figure 1). In Table 7.1 I report the results obtained for the seven experiments discussed in Footnote 2. It should be noted that, even though the average levels of government consumption are very similar for every economy, the sequences of government expenditures differ across experiments.

I find the following:

i. Average welfare losses range from 6.50 percent of the perfect insurance economy's output when inflation is infinite and, consequently there is no possible self-insurance to 1.25 percent when there is a time invariant, zero inflation rate and, therefore, intertemporal substitution of consumption is costless. This result suggests that the monetary insurance arrangement is a good substitute of the perfect insurance arrangement when inflation is low.

ii. The monetary economy and the perfect insurance economy are closer in welfare terms when there are no variations in the rate of change of prices.

iii. The cost of a constant 10 percent inflation for the parameter values chosen is of 1.58 percent of the perfect insurance economy output in economies with time invariant inflation rates.

iv. Average welfare losses resulting from variable inflation are of 0.16 percent of the perfect insurance economies' output and they decrease with increasing rates of inflation.

Section 6. Concluding Remarks

In this paper I study the business cycle implications of alternative insurance technologies using a computable general equilibrium heterogeneous agent environment. I find that the limited monetary arrangement entails larger fluctuations in hours relative to productivity than those that obtain in an identical economy where every risk is costlessly insurable. I also find that in the monetary economy the price level displays a markedly countercyclical behavior. When I evaluate the welfare costs of the monetary arrangement, I find that they range from 6.5% of the perfect insurance economy's output for economies with an infinite rate of inflation to 1.25% for economies with a zero time invariant inflation rate. Natural extensions of this line of research ere the development of computational methods that will allow for the inclusion of capital accumulation in these structures while keeping computational costs manageable and further explorations into the monetary properties of this type of constructs.

* * * * *

Footnotes

1. If the government is constrained to determining the inflation and the labor income tax rates so that they are a function of exclusively the exogenous component of the economy-wide state, then the individual agents' maximization problem is well defined when e(z) and $\theta(z)$ are given and the process on z is known. In this case:

$$\pi(z,z') \Rightarrow d(a,s,z) \Rightarrow f(x,z)$$

where d(a,s,z) denotes the agents' optimal decision rules. This problem is computationally solvable.

On the other hand, if the inflation rates or if the labor income tax rates depend on both the endogenous and the exogenous components of the economy-wide state, i.e. if e=e(x,z) or if $\theta=\theta(x,z)$, in order to have a well defined problem the agent must know both the process on z and the transition on f. Now

$$\pi(z,z') \text{ and } f(x,z) \Rightarrow d(a,s,z) \Rightarrow f(x,z)$$

Computationally, this problem is much harder to solve.

2. In Experiments 2 and 3 I study economies with average inflation rates of 0 and 10% which vary procyclically ±1% about their average. In Experiments 4, 5, and 6, inflation rates were kept time invariant at 0, 4 and 10%. Finally in Experiment 7 there is an infinite rate of inflation. The monetary insurance mechanism is therefore completely shut down and the agents' optimal response is, trivially, to work and to consume the proceeds of their labor each period. Tables with the results of those experiments are available upon request from the author.

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Appendix: Definitions of the Model Aggregates and of the Quarterly Time Series Variables

Given the agents' decision rules, the processes on the exogenous stochastic components of the individual and economy-wide states and an initial distribution of agent types, I generated realizations of the monetary economy's equilibrium processes using the supercomputer. For each period, I computed the following model aggregates:

1. Aggregate Real Gross Income

$$y = \sum_{a,s} w(s,z)n(a,s,z)x(a,s)$$

2. Post-Trade Aggregate Real Currency Holdings

$$m = \sum_{a,s} a'(a,s,z)x(a,s)$$

3. Aggregate Real Consumption

$$c = \frac{m_{-1}}{e(z)} + y(1-\theta) - m$$

4. Aggregate Price Level

$$p = e(z)p_{-1}$$

5. Inflation Rate

$$\frac{\dot{p}}{p} = e(z) - 1$$

6. Aggregate Employment[1]

$$n = \sum_{a,s} n(a,s,z)x(a,s)$$

[1] Since the measure of agents is one, levels and rates are equal.

I then used these model aggregates to construct quarterly time series for a number of the basic macroeconomic variables. In so doing, I followed as closely as possible the procedures actually used for U.S. data. Flows are therefore quoted annually. Subscript i denotes the i-th subperiod of each quarter. Since the model period was chosen to be one-eighth of a year, $i = 1, 2$. I computed the following variables:

1. Real Output

$$y = 4(y_1 + y_2)$$

2. Real Consumption

$$c = 4(c_1 + c_2)$$

3. Real Government Expenditures

$$g = y - c$$

4. Aggregate Labor Input

$$h = 4(n_1 + n_2)0.45$$

5. Real Wage (= productivity)

$$w = y/h$$

6 Quarterly Average Employment Rate

$$n = (n_1 + n_2)/2$$

7. Quarterly Average Nominal Currency Holdings

$$M = (m_1 p_1 + m_2 p_2)/2$$

8. Velocity

$$v = Y/M$$

9. Quarterly Average Price Level

$$p = (p_1 + p_2)/2$$

Table 4.1: The U.S. Economy*
(deviations from trend)

	Volatility	Cross Correlation of Real GNP With								
variable x	(% Std. Dev)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)
GNP	1.801	0.135	0.368	0.628	0.852	1.000	0.851	0.628	0.368	0.134
consumption[1]	0.879	0.387	0.550	0.690	0.783	0.774	0.635	0.446	0.233	-0.004
gov. consumption[2]	3.639	-0.051	-0.095	-0.112	-0.122	-0.049	0.005	0.029	0.059	0.140
hours[3]	1.561	0.014	0.212	0.440	0.688	0.866	0.875	0.764	0.596	0.374
wages[4]	0.954	0.444	0.483	0.502	0.472	0.393	0.267	0.143	-0.009	-0.164
emp. rate	1.065	-0.045	0.147	0.364	0.612	0.823	0.887	0.821	0.668	0.472
M2	1.513	0.607	0.683	0.703	0.625	0.492	0.275	0.044	-0.175	-0.363
velocity[6]	1.845	-0.593	-0.487	-0.294	-0.051	0.246	0.342	0.401	0.432	0.447
Price Level[5]	0.979	-0.638	-0.712	-0.720	-0.665	-0.561	-0.429	-0.291	-0.134	0.023

* Source: Citibank Economic Database. Sample Period: 1954:1 – 1985:2

1 Nondurables and Services

2 Federal Government Purchases

Table 4.2: The Monetary Economy
(deviations from trend)

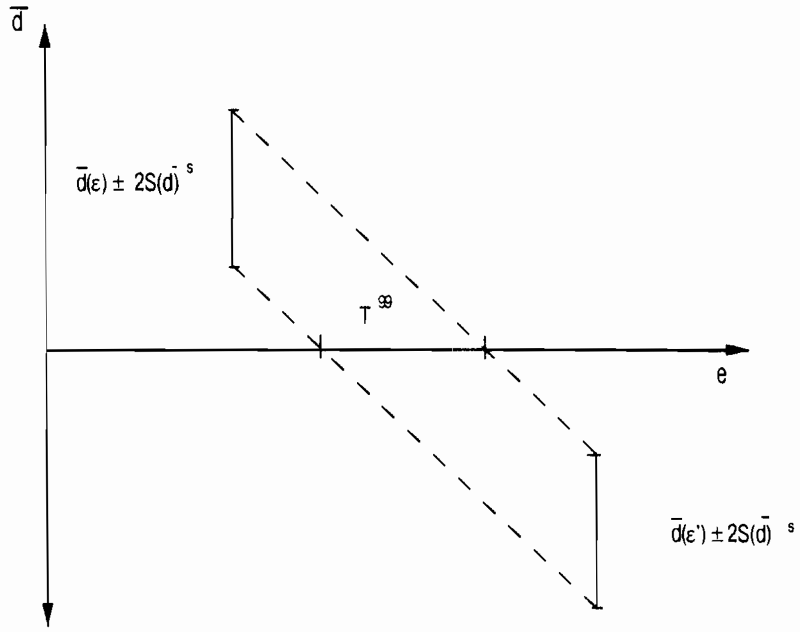
	Volatility	Cross Correlation of Real GNP With								
variable x	(% Std. Dev)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)
output	1.839 (0.002)	-0.030 (0.062)	-0.071 (0.092)	0.079 (0.082)	0.239 (0.088)	1.000 (0.000)	0.244 (0.089)	0.078 (0.078)	-0.064 (0.086)	-0.027 (0.061)
consumption	1.044 (0.001)	-0.063 (0.084)	-0.084 (0.102)	0.057 (0.097)	0.339 (0.083)	0.874 (0.017)	0.518 (0.073)	0.271 (0.078)	0.087 (0.094)	-0.005 (0.069)
gov. consumption	4.688 (0.005)	-0.004 (0.053)	-0.053 (0.084)	0.080 (0.074)	0.144 (0.087)	0.952 (0.006)	0.044 (0.086)	-0.055 (0.073)	-0.151 (0.076)	-0.035 (0.065)
hours	1.283 (0.002)	0.002 (0.051)	-0.050 (0.082)	0.079 (0.074)	0.120 (0.085)	0.925 (0.010)	-0.011 (0.083)	-0.091 (0.072)	-0.173 (0.075)	-0.038 (0.067)
wages	0.812 (0.001)	-0.072 (0.097)	-0.083 (0.104)	0.052 (0.099)	0.351 (0.079)	0.801 (0.025)	0.571 (0.068)	0.319 (0.075)	0.127 (0.092)	-0.001 (0.070)
emp. rate	1.113 (0.001)	0.002 (0.050)	-0.055 (0.082)	0.080 (0.084)	0.120 (0.085)	0.925 (0.010)	-0.014 (0.083)	-0.092 (0.071)	-0.174 (0.075)	-0.039 (0.067)
Money	2.278 (0.002)	-0.154 (0.085)	-0.161 (0.093)	-0.059 (0.085)	0.186 (0.078)	0.746 (0.025)	0.631 (0.061)	0.416 (0.074)	0.201 (0.103)	0.095 (0.084)
velocity	1.294 (0.001)	0.092 (0.092)	0.032 (0.093)	0.063 (0.095)	-0.108 (0.085)	0.080 (0.080)	-0.705 (0.043)	-0.515 (0.070)	-0.314 (0.077)	-0.068 (0.097)
Price Level	0.480	-0.365	-0.400	-0.402	-0.310	-0.064	0.177	0.311	0.369	0.371

Table 4.3: The Perfect Insurance Economy (deviations from trend)

variable x	Volatility (% Std. Dev)	Cross Correlation of Real GNP With x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)
output	1.573 (0.002)	-0.020 (0.063)	--0.053 (0.095)	0.084 (0.088)	0.281 (0.088)	1.000 (0.000)	0.285 (0.088)	0.083 (0.082)	-0.046 (0.088)	-0.014 (0.061)
consumption	0.864 (0.001)	-0.058 (0.094)	-0.052 (0.098)	0.004 (0.109)	0.353 (0.079)	0.717 (0.034)	0.646 (0.048)	0.356 (0.072)	0.152 (0.097)	0.026 (0.072)
gov. consumption	4.688 (0.005)	0.007 (0.050)	-0.041 (0.086)	0.104 (0.077)	0.179 (0.089)	0.932 (0.007)	0.034 (0.085)	-0.082 (0.074)	-0.141 (0.074)	-0.031 (0.070)
hours	1.026 (0.001)	0.019 (0.054)	-0.028 (0.078)	0.060 (0.077)	0.096 (0.087)	0.889 (0.012)	-0.009 (0.087)	-0.118 (0.077)	-0.162 (0.078)	-0.011 (0.070)
wages	0.809 (0.001)	-0.063 (0.088)	-0.068 (0.109)	0.087 (0.101)	0.425 (0.076)	0.814 (0.024)	0.567 (0.067)	0.309 (0.080)	0.115 (0.091)	-0.015 (0.068)
emp. rate	0.905 (0.001)	0.018 (0.053)	-0.028 (0.078)	0.060 (0.078)	0.096 (0.087)	0.889 (0.012)	-0.010 (0.087)	-0.118 (0.076)	-0.162 (0.078)	-0.011 (0.070)

NOTE: The numbers in parentheses are sample standard deviations of the corresponding statistics

Figure 7.1



99% confidence interval for the transfer $T(\varepsilon)$ that makes agents indifferent between the monetary economy and the ertect insurance economy

*Table 7.1 : Welfare Comparisons**

Average $\dot{p}/p$	Constant $\dot{p}/p$	Procyclical $\dot{p}/p$[1]
0.0%	1.25% ± 0.19%[2]	1.55% ± 0.07%[2]
4.0%	2.18% ± 0.14%	2.30% ± 0.08%
10.0%	2.83% ± 0.05%	2.91% ± 0.02%
∞	6.50% ± 0.04%	–

(Percentage of the perfect insurance economy output that makes agents indifferent between the perfect insurance economy and the monetary economy)

*Note that the sequences of government consumptions differ across experiments

1 Root mean squared percentage deviation of inflation = 0.7

2 99% confidence interval