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ON THE FIT OF A NEOCLASSICAL MONETARY MODEL IN HIGH INFLATION: ISRAEL 1972-1990

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ABSTRACT

This paper uses a money in the utility model to show that the Israeli data from the high inflation and post stabilization period fit well the predictions of a simple, neoclassical framework. Specifically, a single parameter money demand equation, that is derived from the model, fits the data much better than a Cagan money demand function. The model's implication on the inflation-seignorage relationship is consistent with the observed fact that while inflation was rising, the inflation-tax revenue remained almost trendless. The labor supply equation derived from the same model is remarkably consistent with the real wage and employment data over the high inflation and stabilization period. There is no evidence for the existence of a "Phillips curve" employment-inflation tradeoff. After the stabilization the demand for money seems to shift. This phenomenon may be due to improvments in transaction technologies as well as to expectations for stabilization during the high inflation. We also show that temporary fixed exchange rate based stabilization and "consumption boom" in the post stabilization period, imply low levels of inflation that are consistent with the model.

1 Introduction

This paper uses a money-in-the-utility model (Sidrauski (1969)) to show that the Israeli data from the high inflation (1979-1985) and post stabilization period (1985-1990) fit well the predictions of a simple, neoclassical framework. Specifically, a single parameter money demand equation, that is derived from the model, fits the data much better than a Cagan money demand function. The latter does not fit well low and high inflation periods at the same time, and therefore, may erroneously indicate that money demand is not stable. The model's implication on the inflation-seignorage relationship is consistent with the observed fact that while inflation was rising, the inflation-tax revenue remained almost trendless. This result contradicts the Cagan-type money demand implication of being on the "wrong side of the Laffer curve". The labor supply equation derived from the same model is remarkably consistent with the real wage and employment data over the high inflation and stabilization period. There is no evidence for the existence of a "Phillips curve" employment-inflation trade-off.

The congruity of the evidence with a neo-classical monetary model suggests that the policy implications of the model are to be taken seriously. In particular, (i) in order to stabilize inflation it suffices to set the expected present value of the government budget deficit (including the central bank) to zero. (ii) There is an immediate welfare gain associated with the stabilization which is estimated to be in excess of 5% of GDP in the Israeli case. (iii) There is no evidence to support the view that stabilization is associated with a loss of output (due to increased unemployment) as would be implied by a Phillips curve.

After the stabilization the model over predicts the demand for money. This phenomenon has been observed for other dis-inflations and may be due to improvements in transactions technology as well as to expectations for stabilization during the high inflation. Temporary fixed exchange rate based stabilization, "consumption boom" and low inflation in the post stabilization period are also consistent with the model.

The consistency of the Israeli data with the neo-classical monetary model strengthen the view presented in Sargent's (1986) classical paper "The end of four big inflations". There Sargent argues, that under rational expectations, with credible stabilization programs, a rapid reduction of inflation rates has very small real costs (if any). Some increases in unemployment rates can be traced to the disruption of economic activity during the final phases of the rapid inflation, or to political events, but not to the stabilization *per se*.[1]

The fact that seignorage is not increasing during the acceleration of inflation is common to all inflationary episodes (see Bental and Eckstein (1990) and the literature cited there). Sargent and Wallace (1987) among others, argue that this phenomenon can be explained by models in which any given feasible money-financed government deficit is associated with two steady-state inflation rates.[2] This last feature of the theory rationalizes in the opinion of many the need to use "heterodox" policies when stabilizing an inflationary economy; only measures such as wage-price freezes and fixed exchange rates will bring the economy to the low, efficient root. [3]

The possibility of multiple steady states is related to the issue of the stability of the behavioral relationships during the inflationary process and across regimes. An important motivation of Cagan's (1956) classical estimation of the demand for money during hyperinflation was to provide evidence in favor of the existence of a stable money demand. However, the extensive empirical work that followed, concluded that the demand for money is not stable.

The model here combines Eckstein and Leiderman's (1992) adaptation of money in the

[1]The lack of any major macro disruptions notwithstanding, Sargent notes that "... the German inflation was far from "neutral" and that there were important "real effects"" (p.94). Garber (1982) demonstrated that there were significant sectorial shifts in Germany in the wake of the stabilization. In particular, the price distortions during the inflationary period caused labor to flow into the investment goods sector in that period, and into the consumption goods sector after stabilization. Wicker (1986) uses the same evidence for Austria and Hungary that Sargent used in an attempt to argue that Sargent's interpretation of the evidence is wrong. That is, there were severe employment effects of the stabilization programs. However, most of these effects can be traced to reductions in government and financial sector employment. Vegh (1992) looks at nine episods and arrives to similar conclusions.

[2]Marcet and Nicolini (1996) show how recurrent episodes of inflation can occur in a multiple-root model and learning.

[3]For example, Bruno (1989) claims that: "...if... the economy was at a high inflation equilibrium, and if, in fact that was a potentially stable equilibrium, then it is no wonder that a fall in the budget deficit, without any accompanying measures that would make the synchronization of nominal magnitudes at a credible low rate of devaluation and wage-price inflation, could shift the economy to an even higher rate of inflation..." (p. 294).

utility model to the Israeli economy. We extend the model to an open economy with traded and non-traded goods (Drazen and Helpman's (1987)) and we add the choice of labor supply. Specifically, we have a representative agent model with intertemporal utility maximization. Every period utility is derived from the consumption of an aggregate consumption good, consisting of a traded and non-traded component, real balances and leisure. The inclusion of real balances in the utility function, represents the transactions services provided by money.[4]

We formally demonstrate the following points:

i) A single-parameter standard money demand equation, that is derived directly from the neo-classical model, fits the data both during the inflation and after the stabilization.[5]

ii) The model fits well the observed seignorage-inflation relationship during the inflation. In particular, it is consistent with the fact that seignorage displays hardly any trend while inflation increases dramatically. There is no need to appeal to the multiplicity of stationary equilibria to obtain this result. The fact that seignorage stayed constant while inflation more than tripled does not provide evidence against the neo-classical theory or against models which possess a unique stationary equilibrium.[6]

iii) The data fits very well the labor supply relationship implied by the model across regimes. In particular, there is no evidence for any inflation-employment trade-off. Figure 2 depicts the behavior of labor supply which is measured as the share of total available time that an average household spends working. As can be seen, the turbulence of the inflation rate depicted in Figure 1 is not reflected in the behavior of the labor supply.[7] These observations do not imply that high inflations and their stabilization do not have real output

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[4]It is well known by now that all models which include transactions services of money (e.g. McCallum (1990)) are equivalent to the Sidrauski model of money and growth.

[5]The post-stabilization velocity remains "too high", see below.

[6]Eckstein and Leiderman (1992) have demonstrate this point, as well as the fact that the Cagan specification does not fit well the inflation-seignorage association in the data. Specifically, the Cagan specification implies unbounded velocities as inflation increases. The data indicates that these velocites remain bounded (see Figure 7). Related to this, the Cagan specification implies an inflation-tax "Laffer curve", while the data displays no such relationship (see Figure 3).

[7]Other measures of the labor supply such as labor force participation, employment rate per household or unemployment rate also show no evidence for the existence of low frequency trade-offs between inflation and these measures.

effects.[8]

iv) Using the estimated parameters of the utility function of the representative agent, we provide an assessment of the welfare loss associated with the Israeli inflation. At an annual inflation rate of about 20% the loss is equivalent to about 4% of GDP, while at the peak of more than 400% (annually) the cost reaches about 10% in terms of GDP.[9]

Despite the remarkable success of the simple model, there are many details which require refinements. One such refinement concerns the post-stabilization velocity. Similar to what has been observed after stabilization in other episodes, the demand for real balances after the Israeli stabilization seems to fall short of its pre-inflationary level (at identical inflation rates). This phenomenon may be due to a positive probability assigned by agents throughout the inflation to the possibility that stabilization will occur.

In addition, we show how the model can be adjusted to consider the commonly observed attempt to maintain low inflation rates by controlling the rate of nominal devaluation. Taking the actual post-stabilization growth rate of GDP and the "consumption boom", as well as the rate of money expansion and the rate of devaluation as given, we show that the model predicts an inflation rate which is close to the persistent post stabilization annual inflation rate of 18%. In this way we confirm that the money demand implied by the model fits well the post-stabilization data.

The rest of the paper is organized as follows. The next section provides a brief review of the Israeli inflation story. The model is presented in Section 3 and empirical implications on money demand and labor supply are presented in section 4. Section 5 looks at the implication regarding seignorage and section 6 at the welfare implications. In section 7 we analyze the role of expectations regarding stabilization in explaining the post stabilization "shift" of the money demand. Section 8 analyses the exchange rate stabilization period and section 9 concludes.

[8]It is well documented by Bruno (1993) that periods of high inflation are typically characterized by low per-capita growth rates. Garber (1982) and Wicker (1986) report on the growth of the banking sector during high inflation periods, and its contraction after stabilization. Israel witnessed a similar development. See also, Melnik (1995) and Aiyagari, Braun and Eckstein (1995) for further discussion.

[9]These costs are due purely to the reduction in real balances. Since the inclusion of real balances in the utility function is an indirect measure of the value added of the transactions services provided by money, the large welfare loss represents some real inefficiencies which are created by inflation.

2 The Israeli Inflation: A Brief History

The story of the Israeli inflation episode has been described by many (e.g. Bruno (1989)), and here we provide just a broad outline.

During the 1970s inflation increased from the previous levels of less than 10% annually to double digit levels. The first significant acceleration occurred in 1978, following a major liberalization of capital controls and the institution of foreign exchange indexed accounts (the PATAMs). These developments, which were not accompanied by any fiscal steps, brought about a major asset substitution away from unindexed assets. Thus, the inflation tax base eroded, and in 1979 inflation rose to about 5% on a monthly basis without any significant change in seignorage revenues, which remained at about 2% of GDP. Inflation continued its upward trend during the first half of the 1980s - it was about 7% monthly from the second half of 1981 to the second half of 1983, then rose to an average of about 14% till the beginning of 1985, and at the final stages (June 1985) peaked at 30% per month (see Figure 1). Seignorage has an upward trend only towards the end of the episode (Figure 2). The size of the primary deficit (government expenses net of interest payments minus tax revenues) was constantly rising throughout the period. This can be inferred from the development of the internal and the external debt out of GDP (Figure 4).

There were several attempts to deal with the crisis prior to the stabilization program of July 1985. These attempts took the form of "package deals" between the federation of labor unions (the "Histadrut"), the organization of the industrialists and the government. The first two parties agreed to mutually refrain from increasing wages and prices and the government "contributed" by slowing the devaluation rate and refraining from increasing the prices of subsidized goods (mainly basic food and transportation). All such attempts failed, as they were not accompanied by any corrective fiscal policies.

In July of 1985 a comprehensive government program was enacted. This program was a heterodox one. In addition to cutting the budget deficit to basically zero (mainly by increasing taxes and cutting subsidies, but also by some cuts in government consumption), the government ordered a freeze on prices of key commodities as well as on wages, and fixed the nominal exchange rate. The US provided a special aid package of 1.5 billion dollars to help stabilize the economy.

Following this program, inflation immediately decreased to 2.1%, 1.4% and 1% per month, and it stayed at about the latter levels until 1992. The national debt (both internal and foreign) decreased sharply, and the primary deficit was (and still is) maintained at about zero. Remonetization took place following the stabilization of the economy, but on the real side there is no adverse reaction. As a matter of fact, the two years following stabilization are characterized by a boom in economic activity and consumption. Correspondingly, the labor market during this post-stabilization phase shows no sign of slackening. There is a slowdown following these two years, but its relation to the stabilization program is unclear.

The Israeli episode of high inflation could easily fit into Sargent's interpretation of the four major European inflations. All of the main features present in the European episodes are also present in the Israeli one. The acceleration of the inflation as well as the characteristics of the stabilization programs are essentially the same (for details see Bental and Eckstein (1989)). Only data constraints of the European economies prevent a formal analysis of the neo-classical monetary growth model for those cases along the lines developed below.

3 The Representative Household

We view the Israeli economy as being populated by a representative household. Every period t the household is endowed with one unit of time. It consumes every period c_{Tt} units of a traded good, and c_{Nt} of a non-traded good, which we assume are regarded as perfect substitutes (to simplify aggregation). In addition, the household derives utility from owning real balances.[10] The value of the real balances is the ratio of the nominal balances held by the household, M_t, and the price index Q_t . The household allocates a proportion ℓ_t of

[10]The inclusion of real balances in the utility function is clearly a simplification. It is easy to construct a model whereby the purchase of consumption goods entails the investment of utility-reducing "effort". If this effort is reduced whenever the purchase of goods is done by money, we obtain our specification as a "reduced form". See also Feenstra (1986) for an elaborate discussion of the equivalence between "money in the utility" formulation and other formulations.

its time to labor market activities, and enjoys the remainder as leisure. The household is assumed to maximize the expected value of the discounted utility stream, which is given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_{Tt} + e_t c_{Nt}, M_t/Q_t, (1-\ell_t)), \tag{1}$$

where $\beta < 1$ is the subjective discount factor and $e_t > 0$ is an exogenous variable that measures the subjective rate of substitution between traded and non-traded goods.[11] E_0 is the expectations operator, conditional on all information available at time 0.

In addition to the time endowment which the household receives every period, it is endowed initially with M_0 nominal units of money and b_0 units of interest-bearing government debt. This debt is fully linked to the price level Q, and bears an interest rate of r_t between period t and $t+1$. Accordingly, every period t the household faces the following budget constraint (written in terms of the traded good):

$$\begin{aligned} &c_{Tt} + (P_{Nt}/\epsilon_t)c_{Nt} + (M_t/\epsilon_t) + (Q_t b_t)/\epsilon_t = \\ &(1-\tau_t)w_t\ell_t + M_{t-1}/\epsilon_t + Q_t[(1+r_{t-1})b_{t-1}]/\epsilon_t. \end{aligned} \tag{2}$$

Here P_{Nt} is the price of the nontraded good in terms of the domestic currency, and ϵ_t is the price of traded goods in terms of the domestic currency.[12] The household sells its labor services for a wage rate of w_t , in terms of the traded good, and pays a proportional tax at the rate τ_t.

Following Drazen and Helpman (1987), the price index Q is given by,

$$Q_t = Q(\epsilon_t, P_{Nt}) \tag{3}$$

where $Q(\cdot,\cdot)$ is homogeneous of degree 1. We denote $q_t = Q_t/\epsilon_t$. Then, due to the homogeneity of $Q(\cdot,\cdot)$, we have $q_t = Q(1, P_{NT}/\epsilon_t) \equiv q(p_t)$, where $p_t = P_{NT}/\epsilon_t$. Notice that p_t is

[11]Our formulation of the preferences here enables us to use the readily available aggregate consumption in the empirical analysis. In Section 8 below we relax the formulation to allow for endogenous substitution between traded and non-traded consumption goods.

[12]This price is represented below by the nominal dollar exchange rate deflated by the U.S. consumer price index.

the price of the non-traded good in terms of the traded good, which is the inverse of the real exchange rate. Let $m_t = M_t/\epsilon_t$ be the real balances in terms of the traded good. Clearly, $M_t/Q_t = m_t/q(p_t)$.

The optimal path chosen by the household must satisfy the following Euler first order conditions:

$$\beta E_t\left[(1+r_t)(Q_{t+1}/Q_t)(\epsilon_t/\epsilon_{t+1})(U_c(t+1)/U_c(t))\right]-1=0, \ (w.r.t.\ \beta_t). \tag{4}$$

$$(U_M(t)/U_c(t))/q_t+\beta E_t\left[(\epsilon_t/\epsilon_{t+1})U_c(t+1)/U_c(t))\right]-1=0, (w.r.t.\ M_t). \tag{5}$$

$$-(U_\ell(t)/U_c(t))+(1-\tau_t)w_t=0, \ (w.r.t.\ \ell_t). \tag{6}$$

The symbol $U_x(t)$ is the marginal utility of x at time t. Equation (4) is the standard optimal intertemporal rule for the allocation of consumption, adjusted for the exchange rate changes. Equation (5) represents the demand for real balances and (6) is the labor supply condition. In addition, if the household is to be indifferent between the traded and non-traded goods, we obtain:

$$p_t = e_t \tag{7}$$

which follows immediately from the assumption that the traded and non-traded goods are perfect substitutes. To simplify, we assume that e_t follows an exogenous path.[13] Equation (7) has very straightforward implications. The real exchange rate changes over time like e_t. Figure 5 shows that despite considerable variations over the sample period, over-all there is no clear trend in e_t.

The gross inflation rate is measured by Q_{t+1}/Q_t , and is denoted by:

$$\pi_{t+1} = Q_{t+1}/Q_t. \tag{8}$$

The nominal interest rate between period $t-1$ and period t, R_{t-1}, is given by:

[13] We endogenize the real exchange rate in section 8 below.

$$(1+R_{t-1}) = (1+r_{t-1})\pi_t. \tag{9}$$

Then, if R_t is known at the beginning of period t, we obtain from (4) and (5):

$$(U_M(t)/U_c(t))/q_t = R_t/(1+R_t). \tag{10}$$

Equation (10) is the demand for real balances, and underlies the generation of inflation through money creation in the economy.

In order to analyze the empirical implications of the above model we choose the following utility function:

$$U(c_T + ec_N, M/Q, (1-\ell)) = \{[(c_T + ec_N)^{(1-\gamma)}(M/Q)^{\gamma}(1-\ell)^{\lambda}]^{\theta} - 1\}/\theta. \tag{11}$$

4 Empirical Implications

In this section we look at the performance of the model with respect to money demand (equation (10)) and labor supply (equation (6)). These two equations, under the specification (11), imply a particular relationship between the consumption velocity of money and the nominal interest rate, and between labor supply and the real wage. The model predicts that these relationships should hold, regardless of the particular fiscal/monetary regime which prevails as well as the production specification of the economy. This is so because the above Euler conditions should hold in any equilibrium and the empirical analysis is invariant with respect to the underlying structure.[14]

4.1 Money Demand

The parameter γ in the utility function (11) can be interpreted as measuring the transaction requirement of money. A low value of γ implies that money is not essential in acquiring

[14] We show in an Appendix that the model we developed above can be embedded in a general equilibrium framework. Accordingly, showing that the particular first order conditions of the consumer problem fit the data is consistent with a broader specification of the economy.

consumption. The higher γ is, the more important the transactions role of money becomes.

According to the specification (11), equation (10) takes the following form:

$$[\gamma/(1-\gamma)][c_t/m_t] = R_t/(1+R_t), \tag{12}$$

where $c_t = c_{Tt} + e_t c_{Nt}$ is aggregate consumption in terms of the traded good.

We rewrite equation (12) as:

$$m_t = [\gamma/(1-\gamma)][(1+R_t)/R_t]c_t. \tag{13}$$

Equation (12) has a natural interpretation as a standard money demand equation: real balances depend positively on consumption with unit elasticity, and negatively on the nominal interest rate, with changing elasticity.

There are several ways to empirically analyze whether equation (12) fits well the Israeli data from 1970 to 1990. First we graph the actual data points of the nominal interest rate and inverse of the consumption velocity (see Figure 7). This Figure shows a remarkable and quite stable relationship between velocity and the nominal interest rate.[15] In Figure 7 we also plot the regression curve implied by (12) (see below) as well as the regression implied by a Cagan money demand specification of the form:

$$m_t/c_t = A\exp(-\alpha R_t). \tag{14}$$

It is quite evident that the specification of our model fits the data much better.[16] This is due to the fact that as inflation and the nominal interest rate increase, our specification implies that the inverse velocity remains bounded by $\gamma/(1-\gamma)$. In the Cagan specification the inverse velocity approaches zero. This implication seems to be counterfactual.[17]

[15]Note the cluster of points which lie a bit closer to the origin. All of these points belong to the post-stabilization era. This is one manifestation of the decline in the money demand. See more on this point below.

[16]Lucas (1993) has a similar result for the U.S. data.

[17]Furthermore, the fitting the Cagan money demand to sub-samples with low inflation and to sub-samples with high inflation would yield very different parameter values. This feature led many to conclude that the demand for money is not stable.

Another simple way is to graph consumption velocity (c_t/m_t) and $(R_t/(1+R_t))$ and see whether they move together as implied by (12). Since (12) represents a low frequency relationship it is reasonable to filter the data, using, say, the Hodrick-Prescott filter, to avoid very high frequency fluctuations in the data.

Figure 6 (using M_1 as the measure of money) shows how well equation (12), which is a single parameter money demand equation, performs. In particular - the consumption velocity (c_t/m_t) follows very closely $R_t/(1+R_t)$ as inflation accelerates, and down again as stability sets in.[18] The demand for money is remarkably stable during the entire period up to the stabilization. Estimating the value of $\gamma/(1-\gamma)$ by taking the average of $[R_t/(1+R_t)]/[c_t/m_t]$, with M_1as a measure of money, is 0.050 (0.014) implying a value of γ of o.048, for the entire sample (1972-1990). For the pre-stabilization sub-period we obtain value of $\gamma/(1-\gamma)$ of 0.055 (0.008) implying values of γ of 0.052. After the stabilization the demand for money seems to have declined: the value of $\gamma/(1-\gamma)$ for this period is and 0.028 (0.003), implying a value of γ of 0.028 (standard deviations in parentheses).

The post-stabilization reduction in the value of γ may be interpreted as indicating a structural decline of the demand for money. Such a shift may be due to the introduction of new payment technologies such as credit cards and ATMs which occurred during the inflationary period. However, as similar shifts have been observed in the European inflations of the early 1920s, other explanations for this phenomenon should also be considered. One such alternative is discussed below (Section 7).

4.2 Labor Supply

The model developed above stipulates that households make optimal decisions regarding their labor-leisure choice (equation (6)). This assumption implies that behavior in the labor market is determined by the supply of labor: any change in the real wage rate is accommodated by a corresponding change in the amount of time allocated by households to labor market activities. Changes in the monetary regime or rate of inflation bear no relationship to this result. The empirical implication of this observation is quite clear: the data should

[18]Note again the gap which develops after the stabilization.

not display any stable "Phillips curve". There should be no correlation between employment and inflation.[19]

Using the parametric specification (11), equation (6), which describes the labor supply, takes the following form:

$$[(\lambda/(1-\gamma)][c_t/(1-\ell_t)] = (1-\tau_t)w_t. \tag{15}$$

Figure 8 presents the time series of $c_t/(1-\ell_t)$ and w_t . The leisure-share of time, $(1-\ell_t)$, is measured by the proportion of time not used for labor market activities by an average household during quarter t.[20] It can be clearly seen that $c_t/(1-\ell_t)$ follows very closely the behavior of w_t (which is measured by quarterly nominal wages deflated by the price of the traded good in terms of domestic currency). The dramatic changes in the rate of inflation during the period cannot be detected in the figure. In particular, the stabilization of July 1985 and the wage and price freeze which were subsequently imposed during the last two quarters of 1985, leave no mark on the figure. The dramatic increase in the real wage starting 1985, should have been accompanied, according to a "Phillips curve approach", by a reduction in employment and increased unemployment. Figures 3 and 8 do not provide evidence to support this view.

The value of $\lambda/(1-\tau)$ can be estimated by the same method that was used earlier for the

[19]Sargent (1986) argued that the end of the European inflations strongly contradict the prediction of a stable Phillips curve. His evidence is based on limited labor market data that could not confront the hypothesis that labor supply is stable.

[20]The exact relationships used for the empirical analysis are the following. The fraction of working time (l) is a ratio between two quantities. The numerator is the total of quarterly labor hours. This is computed from the working hours per employee per week (published by the CBS on a quarterly basis) divided by 7 (days per week) multiplied by the number of days per quarter (which we counted) and the quarterly number of employees (published by the CBS). The denominator is the total potential quarterly working hours, which is given by the total quarterly population at the ages 15-65 (published by the CBS) multiplied by 16 (potential working hours per day) multiplied by the number of days per quarter. The quarterly wage rate is another ratio. First the quarterly wage is computed as the average monthly wage of an employee (published by the CBS) multiplied by 3 (months per quarter). This is divided by the number of hours worked per quarter given by the working hours per employee per week multiplied by 13 (weeks per quarter), and multiplied by the number of working hours per person per quarter (16 times the number of days per quarter).

purpose of estimating γ. In particular, assuming for this purpose that τ remains constant, we computed the average of $w/[c/(1-\ell)]$ over the entire sample period as well as over the pre-stabilization and post stabilization sub-periods. These values are 5.293 (0.396), 5.232 (0.422) and 5.508 (0.165) respectively, with standard deviations reported in parentheses. Using the entire sample average values for γ of 0.048, we obtain that $\lambda/(1-\tau)$ is 5.56 for the entire period, 5.47 for the pre-stabilization period and 5.71 for the post-stabilization period. We notice a remarkable stability of these estimates, and conclude that the supply of labor remained stable throughout the 1970s and 1980s despite the dramatic monetary events of the period.

4.3 Joint GMM Estimation

The estimates reported above were based on simple sample averages using filtered data that emphasis the low frequencies in the data. These estimates are sequential regression results of single equations (one for the money demand and one for the labor supply) using each a single instrument (a constant). Here, we jointly estimate the Euler conditions (4), (5) and (6), for the utility function (11) using Hansen's (1982) *GMM*.[21] The estimates are based on the unfiltered data, and the instruments are a constant, the growth rate of per-household consumption, the growth rate of per-household real balances and one plus the real interest rate.[22] The results (with M_1 as the measure of money) are:

β = 0.997 (0.0131) γ = 0.043 (0.001) θ = -0.412 (0.572) λ = 5.113 (0.059).

The J_t statistic for the over identifying restrictions is 26.70, so that the marginal significance level is 0.001. This means that there is more variation in the quarterly (unsmoothed) data than the model can explain.[23]

As can be seen, the main parameters (γ and λ) are remarkably similar to the estimated values reported above. Furthermore, their standard errors are extremely small. These results

[21] Eckstein and Leiderman (1992) have estimated a closely related set of equations with the same data.

[22] We implicitly assume here that the nominal interest rate (R_t) and the wage rate (w_t) are not known with certainty at period t.

[23] In a closed economy version of the model (where the variation of the exchange rate is not included) the estimated parameters are very close to the ones reported above, but the model is not rejected.

imply that the *GMM* procedure "picked" the constant instrument as the most important one. As for the remaining parameters, the point estimate of the discount rate is quite high, but we cannot reject the hypothesis that the rate of time preference is 1% per quarter. The parameter θ is not precisely estimated, and we cannot reject the logarithmic specification of preferences ($\theta = 0$).

5 Seignorage Implications

As mentioned above, economists found it hard to reconcile increasing inflation rates with trendless (and relatively small) seignorage levels. Here, we investigate how well our model tracks the seignorage collected by the Israeli government during the inflationary period and after stabilization. Since the seignorage data were not used in the estimation procedure above, this investigation may be regarded as a test of the model.

The Israeli government is assumed to consume each quarter (in per-household terms) g_t units in terms of the traded good. Some of this consumption is of non-traded goods, and we assume (to simplify aggregation) that the amount of the non-traded good the government consumes is a fixed proportion of its total consumption. The government finances its expenditures by taxing labor income at the rate τ_t, borrowing at home $(Q_t b_t)/\epsilon_t$ by issuing fully indexed debt, borrowing abroad ϕ_t, and by money creation. The government has to serve its debt at home and abroad. The foreign interest rate, r_t^* is given. Only the government has access to the foreign capital market, and therefore the foreign interest rate and the domestic one need not equalize.[24] Accordingly, the government (per household) budget constraint (in terms of the traded good) is:

$$\begin{aligned} g_t + Q_t(1 + r_{t-1})b_{t-1}/\epsilon_t + (1 + r_t^*)\phi_{t-1} = \\ \tau_t w_t \ell_t + (Q_t b_t)/\epsilon_t + (M_{0t} - M_{0t-1})/\epsilon_t + \phi_t. \end{aligned} \tag{16}$$

[24]This is a realistic feature of the model. The private sector was severely restricted in its access to foreign capital markets throughout the period which we examined. The capital controls are in the process of being liberalized.

We assume that the Israeli government has the choice between two budgetary policies. In one the government finances about 2-3% of GDP of its expenditures by seignorage (defined by $(M_{0t} - M_{0t-1})/\epsilon_t$). In the other budgetary policy the government raises no seignorage through money creation.

¿From the beginning of our sample and until July 1985 the government has chosen to be in the first budgetary regime. Figure 2 shows the seignorage raised by money creation throughout the period as percentage out of GDP. As can be seen, there is a very moderate trend in this series until the end of the inflationary period, where seignorage increases. Eckstein and Leiderman (1992) show in a steady-state analysis that a very slight increase in seignorage suffices to increase the steady-state inflation rate quite dramatically. This result exists in our model as well, since the money demand is the same as theirs.

For the purpose of this section, we estimate the demand for money using M_0 rather than M_1. The estimated value of γ is 0.042. We compute the predicted seignorage as percentage of GDP:

$$\widehat{s}_t/y_t = [(\widehat{M}_t - \widehat{M}_{t-1})/\epsilon_t]/y_t \tag{17}$$

where $\widehat{s}$ denotes the estimated seignorage, and $\widehat{M}$ denotes the estimated demand for the monetary base using equation (13). The actual seignorage is computed by using the money base from the data. The values of y, c, R and Q are taken from the data. Figure 9 displays the actual seignorage and the out-of-steady-state evaluation of the seignorage obtained by equation (16). The result indicates a good fit between the actual and the model's prediction of the seignorage both in terms of levels, magnitude of fluctuations and the moderate trend until 1987. Since in estimating γ we did not use the seignorage data in any direct way, the comparison of the actual and the predicted seignorage provides an additional input for judging the validity of the model. The large gap between the actual and the computed seignorage afterwards can be explained by the dramatic decrease of the reserve requirements, which causes the model to severely over-predict the demand for base money.

6 Welfare Implications

Explicit models like ours facilitate a welfare analysis of the inflation process. More precisely, we can use such models to assess the period-by-period welfare loss due to inflation.

Consider the household's utility function given by (1). The Bellman equation associated with the optimal plan states that the maximal utility the household obtains can be broken down into the contribution of the current period to that utility and the discounted expected future contributions to that utility.

We want to compare the maximal utility the household obtains under the observed policy of the Israeli government to a potential utility which would have been obtained if the government were to cut expenditures and stop inflation.

Suppose that the change in policy is neutral with respect to private consumption, real wages and the ratio of the price index (Q) to the price of traded goods in terms of domestic currency (ϵ). Under these circumstances, the expected discounted value of future utility must be lower under the observed (inflationary) policy. As a result, the difference between the maximal potential single period utility and maximal single period utility under the observed inflation, underestimates the welfare gain obtained from stopping the inflation.

We compute two measures of utility, both with γ=0.04, and λ =5.[25] One is the predicted utility. This utility is computed using the data on consumption and the nominal interest rate in equation (12) to predict the real balances. Using the actual consumption and leisure and the predicted real balances, we compute the predicted utility. The second measure is the potential utility. It is obtained by computing the money demand from equation (12), using the actual consumption data, and a real interest rate of 1% per quarter. Figure 10 displays the single period predicted and potential utilities. As can be clearly seen, the potential utility is higher.[26]

We next compute a measure of the welfare loss due to inflation. Our measure is based on the compensation in income which is needed to make the representative household indifferent between the predicted utility it obtains under the inflationary regime and the potential utility

[25] The value of θ does not play any role in this computation.

[26] A similar picture is obtained when actual real balances are used instead of the predicted ones.

it would have obtained if inflation were to stop.[27] In both cases, we use consumption and leisure as given by the data.

As can be seen from Figure 11, the required compensation reaches a peak of about 10% of GDP at the end of the inflationary episode, and falls but remains positive even after stabilization. It is important to note that the welfare cost of inflation increases substantially as inflation increases. The equivalent utility loss of 10% of GDP explains the urgency the government eventually felt to stabilize the economy.[28]

The welfare cost after stabilization stays high relative to the cost incurred for the same inflation rates at the early 70's because the Bank of Israel held the nominal interest rate at high levels, thus reducing the demand for money. Using the actual data in the calculations, the post-stabilization welfare loss is even higher. This is due to the fact that real balances did not attain their pre-inflationary levels.

As noted above, this gap between real balances before and after inflationary periods (for the same inflation rates) is a common phenomenon. Clearly, using the lower post-stabilization money demand and a value of γ of 0.028 in the welfare calculations, reduces the estimated welfare loss due to inflation. At the peak of the inflation this loss is about 8% of GDP.[29]

7 Money Demand With Expected Stabilization

To provide a possible explanation for the seeming reduction in the money demand after stabilization we follow the work of Flood and Garber (1980), LaHaye (1985) and Drazen and Helpman (1987). These papers studied the shift of the demand for money which occurs during an inflationary process in relation to the expectations agents form with respect to a

[27]The equivalence in terms income is obtained by using the fact that consumption is 60% out of GDP on average.

[28]The stopping of inflation was the only economic goal on the agenda of the "national unity government" formed at the end of 1984.

[29]It should be noted that even at the lower value of γ, the welfare loss due to inflation obtained from our model is substantially higher than that found by models which are based on US data at comparable inflation rates (for example, Lucas (1993)).

stabilization. Here we suggest a simple way to empirically analyze this approach in order to explain the reduction in the estimated value of γ in the post-stabilization period.

As mentioned above, an alternative explanation for this seeming decline in the demand for money is the growth in transactions service provided by the banking sector (in the Israeli case there was a big increase in the use of credit cards, automated tellers etc., see Melnik (1995)). However, these changes took place during the inflation, and therefore should have been manifested in the demand for money before the stabilization.[30]

We assume that throughout the high inflation period households assign a positive probability to the event that the inflation will stop. Clearly, if this event occurs, the return on money will increase at once. Accordingly, the demand for real balances during the inflation reflects the probability assigned to the possibility that the inflation will stop within the next period. Therefore, demand for money is "too *high*" (and the velocity "too low") relative to the observed inflation rate which materializes when stabilization fails to occur. Estimating money demand parameters from the raw data during the inflationary period, as done above, is therefore likely to yield parameter values which bias the estimated demand upwards.

In principle an estimation procedure could be designed which would jointly estimate the parameters of the money demand equation as well as the probabilities assigned to regime changes (both from the inflationary regime to a stable environment and vice versa). However, since we observe only one switch in the regime (from inflation to stability), such a procedure cannot be implemented. Accordingly, we assume that once the economy is stabilized, it does not revert to an inflation.[31] This means that the "true" money demand can be estimated from the post-stabilization data. Using the estimated parameters, we use the pre-stabilization data to estimate the probability of a regime switch.

Specifically, we assume that at every period t the economy may be in one of two regimes. Regime 0 is one in which inflation is maintained at a constant level, so that $\pi_{t+1} = \pi_0 \geq 1$.

[30] Sargent (1986) explains an analogous phenomenon (the substantial post-stabilization increase in central bank notes and demand deposits) by pointing out that after the stabilization the central bank issued bank notes in exchange for real bills, rather than government debt.

[31] With this assumption the model is non-stationary. However, a very small probability that the economy may revert from a stable path to the inflationary one is sufficient to support stationarity. Accordingly, our case should be regarded as a limiting case of stationary environments.

Whenever the change in prices is stabilized, so is the change in the exchange rate. Denoting the change in the price of traded goods in terms of the domestic currency by η_{t+1}, this assumption implies that after stabilization $\eta_{t+1} = \eta_0 \geq 1$. Alternatively, regime 1 may prevail, for which π_{t+1} and η_{t+1} may be changing (increasing) . households know which of the two regimes prevails at the beginning of period t. They do not know whether the regime change will occur during the prevailing period.[32] However, conditional on the regime, households are assumed to know what the price changes and devaluation will be. We assume that the inflationary regime will change during period t is φ_t.

The labor-leisure decision, as implied by equation (6), is independent of the probability of a change in regime. However, the demand for money as given by (5) does depend on the expected future regime. Given our specification of preferences, equation (5) becomes:

$$[\gamma/(1-\gamma)](c_t/m_t) + \beta E_t\{(1-\varphi_t)(1/\eta_{1t+1})(1/\widehat{c}_{t+1}) + \varphi_t(1/\eta_0)(1/\widehat{c}_0)\} - 1 = 0 \qquad (18)$$

where $\widehat{c}_{t+1}$ denotes the consumption growth c_{t+1}/c_t if the inflationary regime continues to prevails, and $\widehat{c}_0$ otherwise.

We simplify by assuming that the consumption growth rate is independent of the regime change. In this case, equation (18) can be used to obtain the probability associated by the households to the event that the inflationary regime will change at period t:

$$\varphi_t = \frac{1 - [\gamma/(1-\gamma)](c_t/m_t) - \beta(1/\widehat{c}_{t+1})(1/\eta_{t+1})}{\beta(1/\widehat{c}_{t+1})[(1/\eta_0) - (1/\eta_{t+1})]} \qquad (19)$$

Thus, if the possibility of a regime change is ignored, using an estimated value of $[\gamma/(1-\gamma)]$ which is obtained from a money demand equation like (5) will overestimate the demand for money during an inflationary period. Wrongly assuming that the inflationary regime continues with probability one, the demand for money should be low, reflecting the high nominal interest rates associated with the inflation. However, households who expect (with

[32]Ruge-Murcia (1995) estimates a model of the Israeli inflation in which agents infer from the observed data whether a regime change has taken place. We assume that once such a change has taken place, it is immediately recognized by everyone.

some positive probability) a regime change, will hold larger real balances in accordance with that probability.

To estimate an average probability of a regime change during the inflationary period, we substitute the estimated value of $\gamma/(1-\gamma)$ from the post-stabilization data into (19), use the observed values of the velocity (c_t/m_t), the consumption growth $\widehat{c}_{t+1}$ and the change of the price of traded goods in terms of the domestic currency η_{t+1}. The post-stabilization value of the latter, η_0, is the average change of the price of traded goods in terms of the domestic currency after stabilization has occurred. The average probability assigned to a regime change in the coming quarter, φ, obtained in this way, is 0.75. This is a high probability which reflects the relatively large reduction in the demand for money after the stabilization. However, this value constitutes an upper bound, as we assigned a probability of zero to the event that after stabilization there could be a return to the inflationary regime. Clearly, if households assign a positive probability to the resumption of inflation, then the estimated value of γ after the stabilization underestimates its true value.[33]

One way to illustrate the correction achieved by this extension to the money demand equation, is to compare the residuals obtained from the parameters estimated using the GMM procedure over the entire sample period which ignores the probability of a regime change to the residuals obtained by the procedure described above. Define the GMM residuals by

$$u_{tGMM}{=}1/[\Gamma_{GMM}][1-\beta(1/\eta_{1t+1})(1/\widehat{c}_{t+1})]-(c_t/m_t) \tag{20}$$

where $\Gamma_{GMM}=\gamma_{GMM}/(1-\gamma_{GMM})$, and

$$u_{tBE}{=}1/[\Gamma_{PS}][1-\beta(1/\widehat{c}_{t+1})[\varphi(1/\eta_{1t+1})+(1-\varphi)]-(c_t/m_t) \tag{21}$$

where $\Gamma_{PS}=\gamma_{PS}/(1-\gamma_{PS})$ stands for the post-stabilization parameter values. As can be seen from Figure 12, the GMM residuals have a clear trend, where all post-stabilization residuals are negative. The residuals of the alternative procedure (denoted "BE" residuals) are basically trendless. They become large and negative about two years prior to the stabilization, reflecting the aforementioned decline in the probability assigned to a regime change which the model implies.

[33]The high estimated value of φ would be lower if the value of γ is decreasing during the high inflation period.

8 Post Stabilization Inflation

After stabilization, inflation settled on an annual rate of 18%. During the same period the average annual nominal devaluation amounted to 7% with no devaluation at the initial period. In addition, aggregate consumption grew by an annual rate of 7.4%, while GDP grew, on average, at 3.8%.[34] Clearly, the large deviation of the rate of nominal devaluation from inflation could not persist forever and, in fact, the gap has been closed during the early 1990's. Still, the question is whether as a temporary phenomenon these observations are consistent with our model. Here, we show that if we take the paths of the exchange rate devaluation, monetary expansion and output growth as exogenous, the observed inflation rate is consistent with the model's predictions.

The formulation above in which the traded and non-traded goods are perfect substitutes is not well suited to discuss the relationship between nominal exchange rate changes and inflation. In particular, an equilibrium in which both traded and non-traded goods are consumed requires $e_t = P_{Nt}/\epsilon_t$, where e_t is the exogenous marginal rate of substitution between both types of consumption goods. Clearly, any small deviation from this condition means that either of the two types of goods will not be consumed. To avoid this extreme implication, we relax the assumption that the marginal rate of substitution between traded and non-traded goods is independent of prices.

For this purpose we omit the labor choice, and amend the periodic preferences to be $U(c_{Tt}, c_{Nt}, M_t/Q_t)$. Under these circumstances the Euler first order conditions become:

$$(1 + r_t)\beta E_t(\pi_{t+1}/\eta_{t+1})(U_{cT}(t+1)/U_{cT}(t)) - 1 = 0, \tag{22}$$

and

$$\epsilon_t(U_M(t)/U_{cT}(t)) + \beta E_t(1/\eta_{t+1})(U_{cT}(t+1)/U_{cT}(t)) - 1 = 0. \tag{23}$$

[34]This post stabilizaton "consumption boom" is common to many economies which stabilized their currency. It may be explained as a result of a wealth affect (see, for example, Rebelo and Vegh (1995)).

The new condition pertains to the static choice between traded and non-traded goods:

$$(\epsilon_t/p_{Nt})(U_{cN}(t)/U_{cT}(t)) - 1 = 0. \tag{24}$$

To facilitate the comparison between this specification and the previous one, we specify:

$$U(c_{Tt}, c_{Nt}, M_t/Q_t) = \{\{[(c_{Tt})^{\nu}(c_{Nt})^{(1-\nu)}]^{(1-\gamma)}(M_t/Q_t)^{\gamma}\}^{\theta} - 1\}/\theta. \tag{25}$$

In addition, we specify for the price index:

$$Q_t = (\epsilon_t)^{\alpha}(p_{Nt})^{(1-\alpha)}. \tag{26}$$

We use these specifications in order to derive a relationship between the growth rate of the economy, the money supply growth, the rate of change of the price of traded goods in terms of the domestic currency and the rate of inflation.

We use equation (24), which becomes:

$$[(1-\nu)/\nu](\epsilon_t/p_{Nt})(c_{Tt}/c_{Nt}) - 1 = 0, \tag{27}$$

together with equation (26) to compute:

$$\pi_{t+1} = (\epsilon_{t+1}/\epsilon_t)[(c_{Tt+1}/c_{Tt})(c_{Nt}/c_{Nt+1})]^{(1-\alpha)}. \tag{28}$$

To simplify, we concentrate on a special case in which the (gross) rates of change of all relevant variables is constant. In particular, let the economy grow at a rate g. We assume that consumption of non-traded goods grows at the same rate. Let the consumption of traded goods grow at a rate x. Let the money supply grow at μ, and let the real interest rate remain constant.

Under these circumstances, the demand for money, derived from equations (22) and (23), and using:

$$U_{cT}(t+1)/U_{cT}(t) = \\ (c_{Tt+1}/c_{Tt})^{\nu(1-\gamma)-1}(c_{Nt+1}/c_{Nt})^{(1-\nu)(1-\gamma)}((M_{t+1}/Q_{t+1})/(M_t/Q_t))^{\gamma}, \tag{29}$$

becomes:

$$[\gamma/\nu(1-\gamma))][c_{Tt}/(M_t/\epsilon_t)] = 1 - (1/\eta)[(1/x)(g)]^{(1-\alpha)}]/(1+r)]. \tag{30}$$

Note that equation (30) is perfectly analogous to (12) when $\eta = \pi$, and $x = g$. From equation (30) we obtain:

$$x = c_{Tt+1}/c_{Tt} = (M_{t+1}/M_t)/(\epsilon_{t+1}/\epsilon_t) = \mu/\eta. \tag{31}$$

Equation (31) implies that consumption of traded goods is more likely to grow at a rate which exceeds the economy's growth rate as the growth of the money supply exceeds the rate of change of the price of traded goods.

Substituting equation (31) into (28), and using our assumptions about the growth rates, we get that the inflation rate is:

$$\pi = \eta^{\alpha}(\mu/g)^{(1-\alpha)}. \tag{32}$$

Equation (32) implies that any expansion of the money supply at a rate that exceeds the economy's growth rate ($\mu > g$) while holding the price of traded goods in terms of domestic currency fixed ($\eta = 1$), generates inflation. However, if the nominal exchange rate is maintained at a fixed level, then $\eta = \pi*$, where $\pi*$ denotes the gross inflation abroad. In this case, inflation is given by:

$$\pi = (\pi*)^{\alpha}(\mu/g)^{(1-\alpha)}. \tag{33}$$

In particular, the domestic inflation can be controlled (for a while) by halting the nominal devaluation.

This policy cannot be maintained forever. In the long run, the money supply has to be expanded at the growth rate of the economy (which is also the growth rate of consumption of both the traded and non-traded goods) and the nominal devaluation rate should match the rate of the foreign inflation, to keep the price of traded goods in terms of domestic currency constant. With this combination, the price level remains stable.

As pointed out above, some aspects of the post-stabilization behavior of the Israeli economy matches this story quite well. On a yearly basis, the (geometrically averaged) gross growth rate of M_1 (μ) for the years 1986-9 was 1.324. The average nominal devaluation against the dollar was 1.069, while prices in the US rose on average by 1.036, implying a value of η of 1.032. Using these number in equation (31) yields a predicted average growth rate of the consumption of traded goods of 1.28, a number which seems too high. However, this result, when substituted into equation (28) yields a quite reasonable prediction for the inflation rate, as given by equation (32). In order to obtain this estimate, we need to assess the value of α.

According to calculations of the Bank of Israel, 44.2% of the output of the business sector in these years was traded (the 1995 report, Table B-2). The business sector constituted about 65% of GDP (Table B-1). This implies that the weight of traded goods is about 29% in GDP, assuming that only the business sector produces traded goods.[35] Assuming that the weight of traded and non-traded goods in the CPI matches these calculations, we obtain a value of $\alpha = 0.29$. Thus, equation (32) yields an inflation rate of 1.20, which is very close to the actual average yearly inflation in these years of 1.18. In fact, this calculation demonstrates that given the performance of the real side of the economy and the expansion rate of the money supply, the money demand implied by the model fits well the post-stabilization data.

9 Conclusion

We have used a very simple model to tell the story of inflation and stabilization. We used the Israeli case, and describe the behavior of inflation, consumption, real balances, employment, exchange rate, wages and seignorage. The story told by the model, despite its simplicity, is remarkably close to reality. That is, the co-movements of the variables as predicted by the model fit well the main observed features of the data.

There are certain refinements of the basic model which help improve its performance. We show that a modification may be able to account for the seeming decline of the demand for real balances after stabilization. Adding uncertainty about the stabilization date implies that the demand for real balances during the inflation does not decline as much as would be predicted if the inflation were to increase with certainty. Another modification is used

[35] Consumption is likely to be even more biased towards non-traded goods.

to demonstrate that the model is consistent with the post-stabilization inflation while the nominal exchange rate remains fixed at a given level. As the fixed exchange rate policy is not sustainable in face of an inflation rate that exceeds that of the trade partners, the success of the model in this case as well as the performance of the simple model before and after the stabilization indicate that the model is not very sensitive to the temporariness of the current reginme and to expected regime changes.

The success of the approach lends credence to the welfare and policy implications of the model. Specifically, using the simple model, we measure a substantial welfare loss due to high inflation and no output cost of stopping it. These features may not be consistent with views held by certain economists, but are remarkably consistent with the political popularity of stopping inflation.

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APPENDIX

In this Appendix we describe a simple general equilibrium model which embeds the household optimization problem of Section 3 in the text. By doing so, we show that the model we estimate is consistent with a general equilibrium setting.

Production

The economy produces a traded good and a non-traded good. To simplify, we ignore all factors of production except labor.

Aggregate non-traded goods production, Y_N, is given by:

$$Y_{Nt} = A_{Nt} L_{Nt}^{\delta} \,,\; 0 < \delta < 1 \tag{A1}$$

where L_{Nt} denotes aggregate labor input into the non-traded good production, and A_{Nt} follows a stochastic process with growth.

Traded goods production, Y_T, is given by:

$$Y_{Tt} = A_{Tt} L_{Tt} \tag{A2}$$

where L_{Tt} denotes aggregate labor input into the non-traded good production, and A_{Tt} follows a stochastic process with growth (with the same mean as A_{Nt}).

Profit maximization

For simplicity assume that the entire sector of the non-traded good consists of a single, price-taking, profit-maximizing firm (clearly, any exogenously given finite number of firms would yield an equivalent characterization). The traded good sector consists of any number of price-taking and profit-maximizing firms. The zero-profit condition in the traded good sector and profit maximization in the non-traded good sector imply:

$$W_t = \epsilon_t A_{Tt} \tag{A3}$$

and

$$W_t = P_{Nt} A_{Nt} \delta L_{Nt}^{\delta - 1} \tag{A4}$$

where W_t denotes the nominal wage, and P_{Nt} and ϵ_t are the prices of the non-traded and traded goods in terms of the domestic currency, as defined in the text.

Equation (A4) implies a nominal profit, Z_{Nt}, in the non-traded good sector of

$$Z_{Nt} = (1-\delta)Y_{Nt}. \tag{A5}$$

We also have the definitions from section 3:

$$\begin{aligned} w_t &= \frac{W_t}{\epsilon_t}, \\ p_t &= \frac{P_{Nt}}{\epsilon_t}, \\ q_t &= \frac{Q_t}{\epsilon_t}. \end{aligned} \tag{A6}$$

Households

The household problem is as defined by the preferences (1) and budget constraints (2) in section 3. The budget constraint is corrected for the per-household profits denominated in terms of the traded good, z_t, generated by the non-traded good sector, which are taken as lump-sum:

$$\begin{aligned} &c_{Tt} + (P_{Nt}/\epsilon_t)c_{Nt} + (M_t/\epsilon_t) + (Q_t b_t)/\epsilon_t = \\ &(1-\tau_t)w_t\ell_t + M_{t-1}/\epsilon_t + Q_t[(1+r_{t-1})b_{t-1}]/\epsilon_t + z_t. \end{aligned} \tag{2'}$$

The government

Each period, the government consumes G_{Tt} units of the traded good and G_{Nt} units of the non-traded good. The government budget constraint is:

$$\begin{aligned} &G_{Tt} + \frac{P_{Nt}}{\epsilon_t}G_{Nt} + Q_t(1+r_{t-1})B_{t-1}/\epsilon_t + (1+r_t^*)\Phi_{t-1} = \\ &\tau_t w_t L_t + (Q_t B_t)/\epsilon_t + (\widehat{M}_{0t} - \widehat{M}_{0t-1})/\epsilon_t + \Phi_t. \end{aligned} \tag{A7}$$

Equation (A8) is equivalent to equation (16) in section 5, except that equation (A8) is written in aggregate terms, so that L_t is total employment, B_t is the stock of CPI indexed bonds, Φ_t is the aggregate government foreign debt, and $\widehat{M}_{0t}$ is the aggregate stock of outside money at period t.

Resource constraints

Total uses of the non-traded good must equal production:

$$C_{Nt} + G_{Nt} = Y_{Nt}, \tag{A8}$$

where C_{Nt} denotes aggregate private consumption of the non-traded good.

The traded good can be imported, so that:

$$C_{Tt} + G_{Tt} = Y_{Tt} + IM_t, \tag{A9}$$

where C_{Tt} denotes aggregate private consumption of the traded good and IM_t is the net import.

The current account deficit is matched by a capital account surplus:

$$IM_t = \Phi_t - (1 + r_t^*)\Phi_{t-1}. \tag{A10}$$

The labor market equilibrium requires:

$$L_{Nt} + L_{Tt} = L_t \tag{A11}$$

and

$$L_{Nt} + L_{Tt} = N_t \ell_t, \tag{A12}$$

where N_t is the number of households in period t.

In addition, we require:

$$\widehat{M}_{0t} = N_t M_t, \tag{A13}$$

$$B_t = N_t b_t \tag{A14}$$

$$C_{Tt} = N_t c_{Tt}, \tag{A15}$$

$$C_{Nt} = N_t c_{Nt}, \tag{A16}$$

and

$$Z_t = N_t z_t. \tag{A17}$$

Equilibrium

An *equilibrium* is a stochastic path of $\{c_{Nt}, c_{Tt}, M_t, b_t, \ell_t, Y_{Nt}, Y_{Tt}, L_{Nt}, L_{Tt}, L_t,$
$C_{Nt}, C_{Tt}, W_t, w_t, P_{Nt}, \epsilon_t, p_t, Q_t, q_t, \pi_t, z_t, Z_t, R_t, r_t, IM_t, \Phi_t, \widehat{M}_{0t}\}$
given a stochastic path of $\{A_{Nt}, A_{Tt}, G_{Nt}, G_{Tt}, N_t, e_t, r_t^*, \tau_t, B_t\}$ for $t = 1, 2, ...$ and given initial conditions $\widehat{M}_{00}, \Phi_0$,and B_0, such that the following equations hold:

(i) Household problem: Budget constraint (2') and Euler equations (4), (5) and (6).

(ii) Government budget constraint: Equation (A7).

(iii) Production and profits: (A1), (A2) and (A5).

(iv) Resource Constraints: Equations (A8), (A9), (A10) and (A11).

(v) Prices: Equations (3), (7), (8), (9), (A3), (A4), and (A6).

(vi) Aggregation: (A12), (A13), (A14), (A15), (A16) and (A17).

Remark

In general, the equlibrium path generated by this environment is not Pareto optimal. Neverthelss, there are examples in the literature of similar economies in which equilibria have been shown to exist. Therefore we conjecture that under sufficient regularity conditions, an existence proof can be constructed also for this environment.

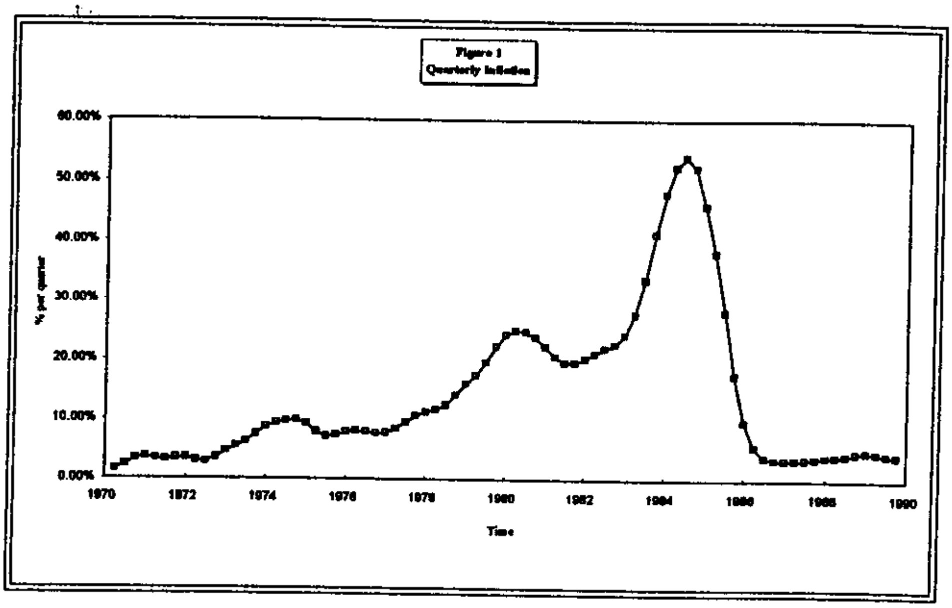

Figure 1: Quarterly Inflation

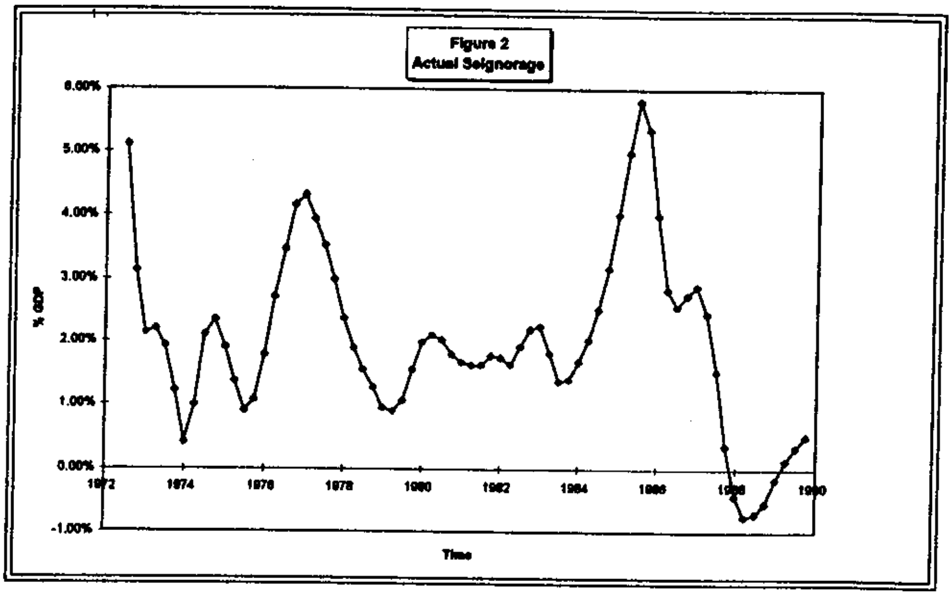

Figure 2: Actual Seignorage

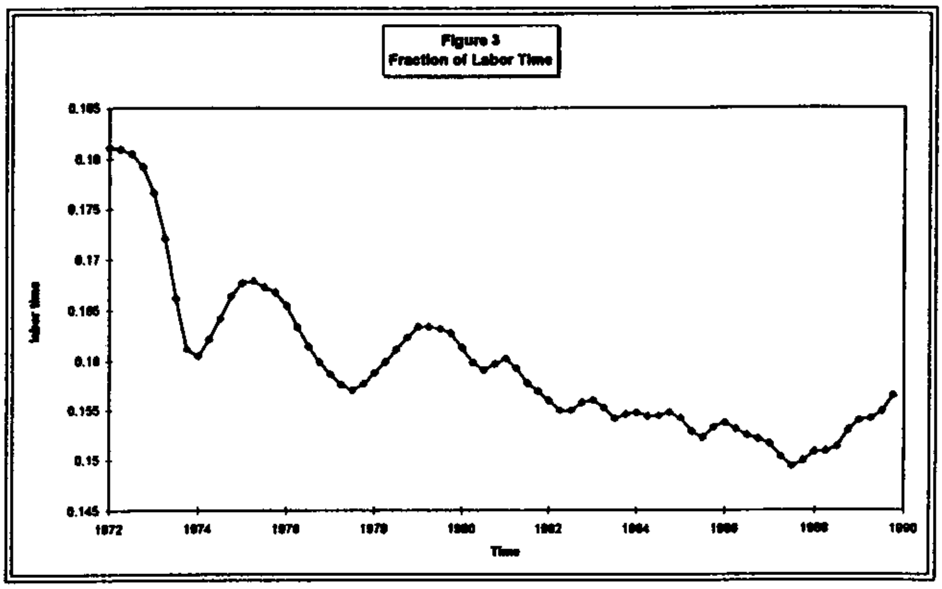

Figure 3: Fraction of Labor Time

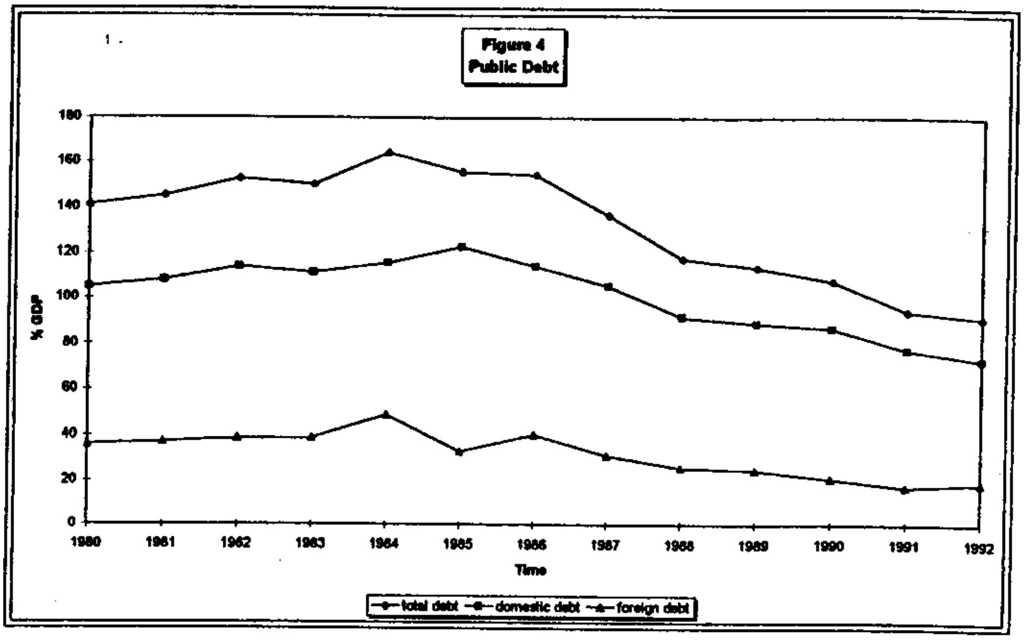

Figure 4: Public Debt

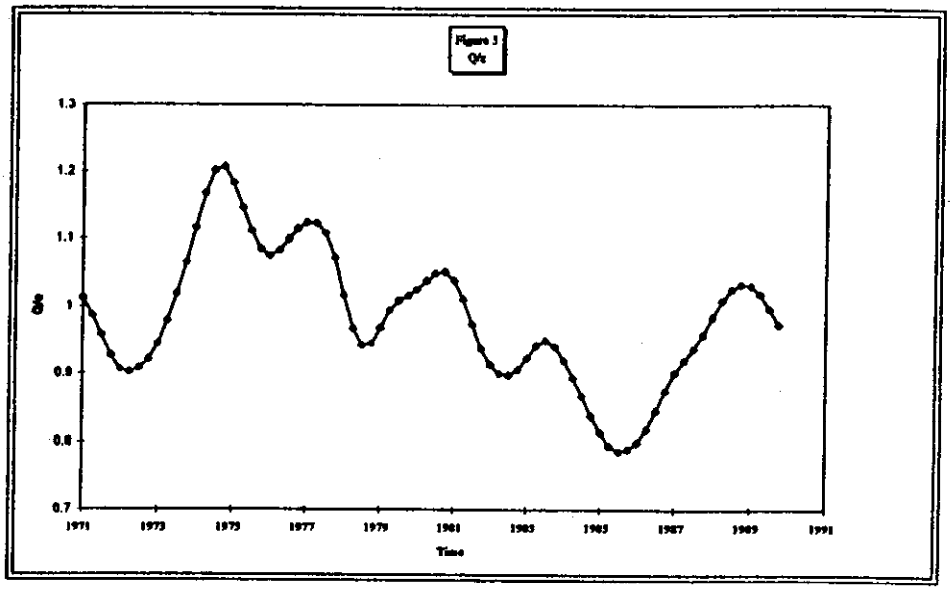

Figure 5: Normalized CPI

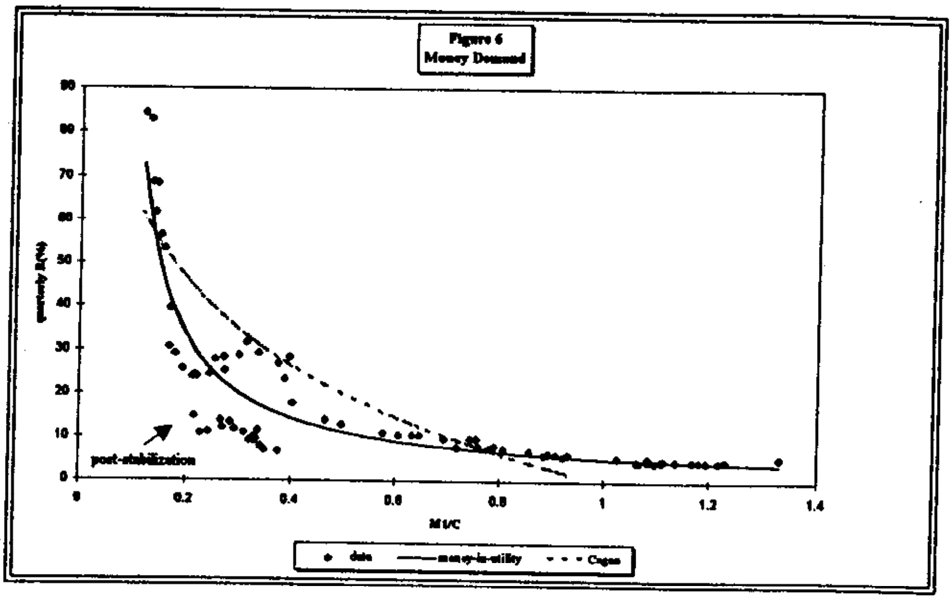

Figure 6: Money Demand

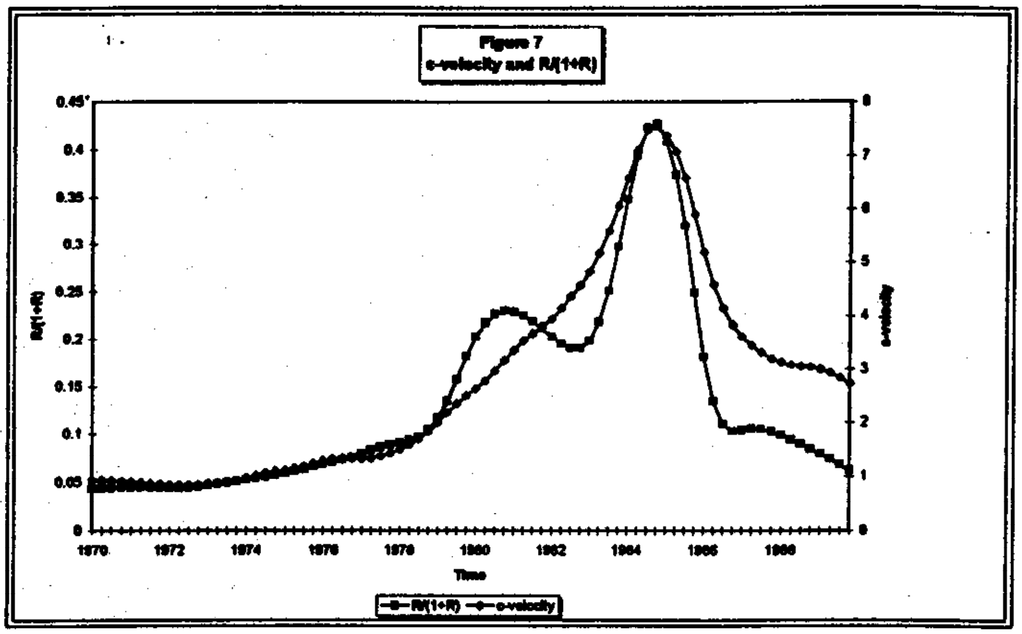

Figure 7: Consumption Velocity and Interest Rate

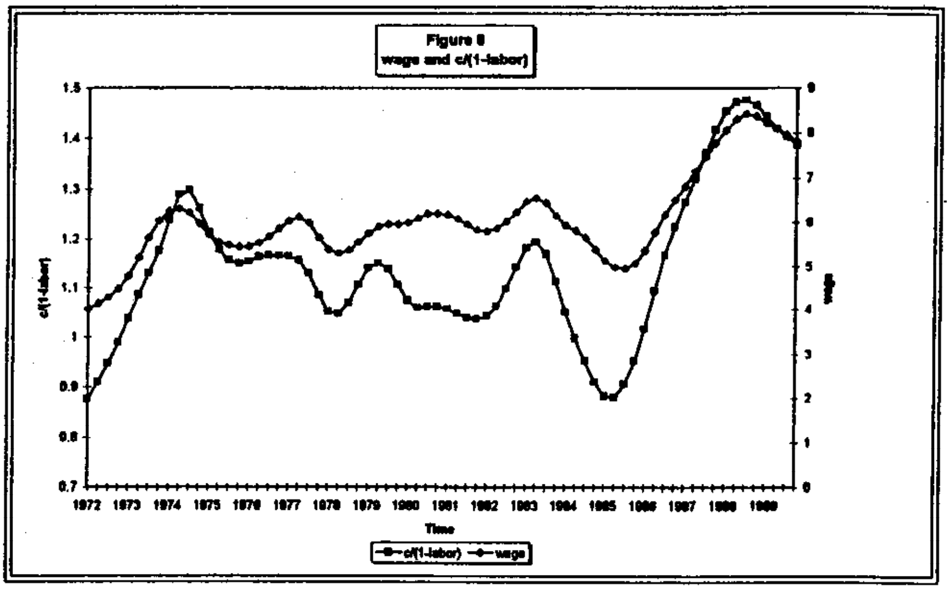

Figure 8: Wages and Labor

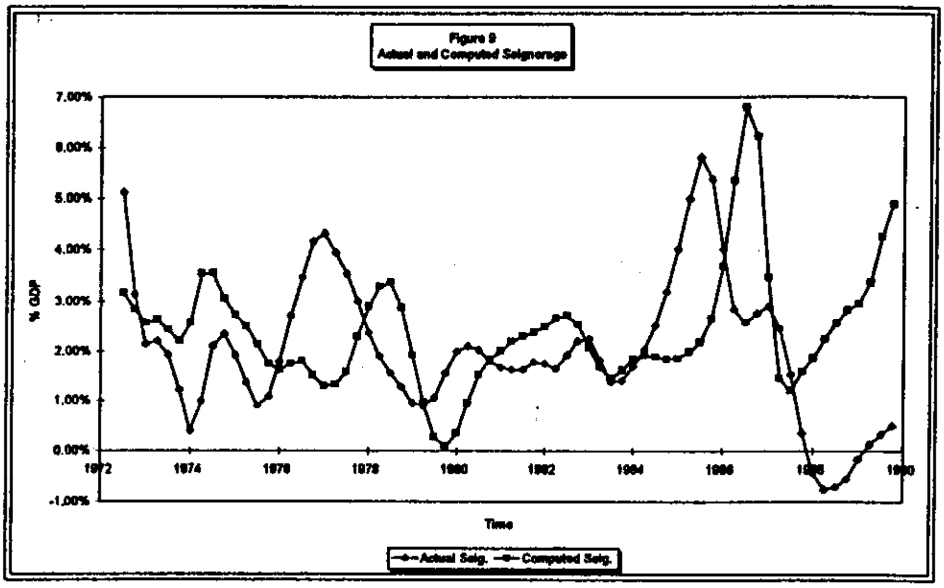

Figure 9: Actual and Computed Seignorage

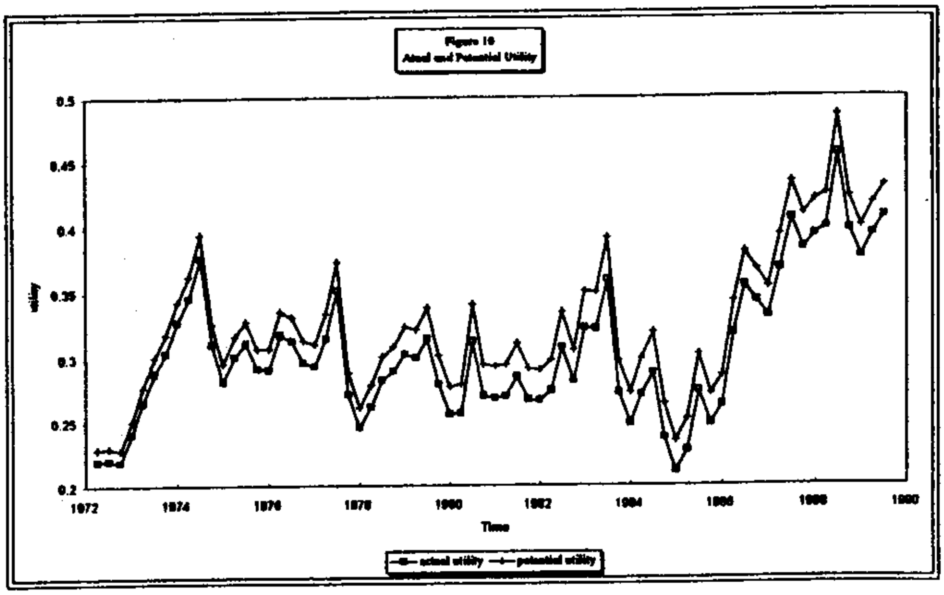

Figure 10: Utility

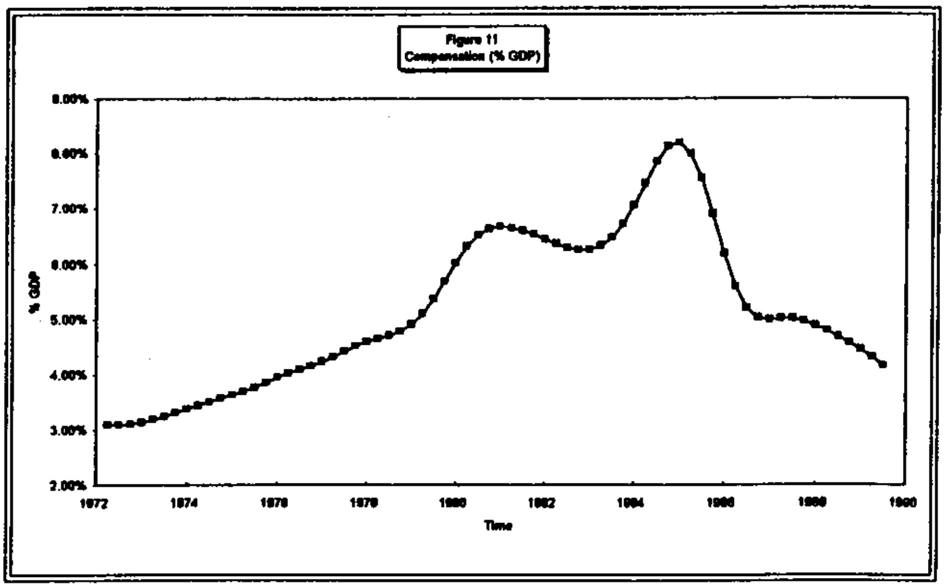

Figure 11: Compensation

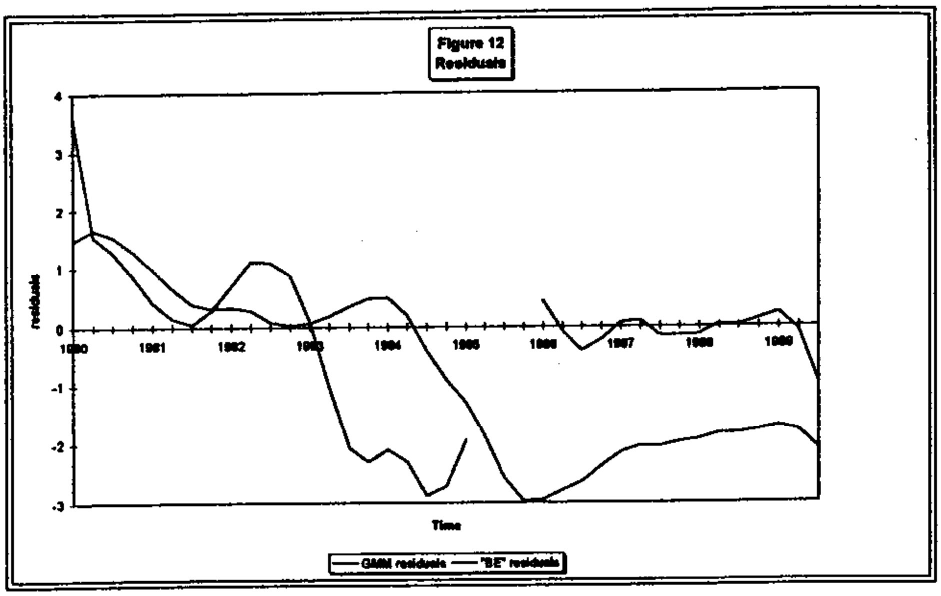

Figure 12: Residuals