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CREDIBILITY AND SIGNALING IN DISINFLATIONS
A Cross Country Examination

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RÉSUMÉ

Cet article propose un modèle avec demande de monnaie dont le coût d'opportunité est soumis à des changements de régime. Un régime étant entièrement défini par la moyenne et la variance du taux d'inflation, on émet l'hypothèse qu'il dépend du choix de politiques gouvernementales. Un taux d'inflation à atteindre est déterminé dans le cadre d'un programme de stabilisation. Les agents économiques ne peuvent toutefois observer directement si les actions du gouvernement correspondent avec le taux recherché. Ils doivent produire des inférences statistiques à partir d'observations sur les taux d'inflation et la croissance du stock de monnaie. Il est de plus admis que les annonces gouvernementales peuvent fournir davantage d'information, parfois véridique, en ce qui concerne le régime choisi.

Cette modélisation est estimée et testée au moyen de données relatives aux périodes de forte inflation en Israël et en Argentine. Les résultats suggèrent que le programme de stabilisation de juillet 1985, entrepris avec succès en Israël, était plus crédible que la tentative précédente de novembre 1984 ou que les programmes argentins. Il semble que les signaux émis par le gouvernement contribuent à simplifier de manière significative le problème d'inférence, ainsi qu'à augmenter la vitesse d'apprentissage des agents. Ils peuvent cependant, et sous certaines conditions, contribuer à hausser la volatilité du taux d'inflation. L'instauration d'un programme de stabilisation de l'inflation se traduit par des gains en bien-être dus à la hausse temporaire des encaisses réelles; s'ils sont assez importants, ces gains peuvent inciter les agents à augmenter leurs encaisses réelles à court terme, et ce, même s'ils ont des incertitudes quant à la nature de la politique gouvernementale et au succès éventuel de la tentative de stabilisation. Statistiquement, les restrictions du modèle ne peuvent être rejetées à un niveau significatif de 1 %.

Mots clés : apprentissage, crédibilité, annonces gouvernementales, signalisation, inflation, changements de régimes, modèles non linéaires, demande de monnaie

ABSTRACT

This paper develops a model of money demand where the opportunity cost of holding money is subject to regime changes. The regimes are fully characterized by the mean and variance of inflation and are assumed to be the result of alternative government policies. Agents are unable to directly observe whether government actions are indeed consistent with the inflation rate targeted as part of a stabilization program but can construct probability inferences on the basis of available observations of inflation and money growth. Government announcements are assumed to provide agents with additional, possibly truthful information regarding the regime. This specification is estimated and tested using data from the Israeli and Argentine high inflation periods. Results indicate the successful stabilization program implemented in Israel in July 1985 was more credible than either the earlier Israeli attempt in November 1984 or the Argentine programs. Government's signaling might substantially simplify the inference problem and increase the speed of learning on the part of the agents. However, under certain conditions, it might increase the volatility of inflation. After the introduction of an inflation stabilization plan, the welfare gains from a temporary increase in real balances might be high enough to induce agents to raise their real balances in the short-term, even if they are uncertain about the nature of government policy and the eventual outcome of the stabilization attempt. Statistically, the model restrictions cannot be rejected at the 1% significance level.

Key words : learning, credibility, government announcements, signaling, inflation, changes in regime, nonlinear models, money demand

1. Introduction

This paper estimates a model of learning where agents must make inferences about government policy using publicly available data and government announcements. In particular, I consider a model of money demand where the opportunity cost of holding liquid assets is subject to changes in its stochastic process as a result of discrete changes in government policies. The rate of inflation is assumed to be generated by either of four possible regimes [Hamilton (1989)]. The states are fully characterized by the mean and variance of inflation and are defined by the possible combination of two policy tools employed by the government to affect the inflation rate and agents' beliefs, namely (*i*) fiscal and monetary policies and (*ii*) government announcements. Since the demand for money is a function of expected inflation [Cagan (1956)], agents are required to make an assessment about current and future government policy as manifested by the inflation regime.

It is assumed that agents are unable to observe whether government policies are or are not consistent with the desired lower inflation rate. However, they can construct probability assessments concerning the regime using currently available observations of inflation and money growth. More precisely, agents employ Bayes' Rule to infer, conditional on the data, the state that has generated the observation of inflation. Since these probabilities are revised in every period as new data becomes available, there is a sense in which agents are allowed to learn over time the particular policy followed by the government. Importantly, the agent's information set is assumed to include government announcements that might provide them with additional, possibly truthful information regarding the regime.

The framework above is employed to empirically examine the role of credibility and government signaling on inflation stabilization. As an application, this paper examines the cases of Israel and Argentina, where a disinflation strategy that advocates a substantial role to government signaling was applied. This approach involves the government's announcement of a temporary period of controlled prices (including the ones of labor and foreign exchange), that is intended to signal the switch to a new, lower inflation rate to be sustained with changes in the fundamentals to be implemented during this phase. Agents are left to infer whether these government policies are or are not consistent with the inflation target. For the countries under study, it may have been the case that given insufficient changes in fundamentals, agents correctly inferred that price and wage controls were just masking the effects of high rates of money growth and that high inflation would return once controls were lifted. In this sense the government's pledge and its stabilization program *would not* have been credible. On the other hand, agents may have inferred on the basis of a temporarily low inflation rate that there had been a substantial reform in government's policies. In this case the stabilization program *would* have been view as credible. One advantage of considering these particular episodes is that is allow us to associate the government announcement/signal with an objective, observable, and persistent economic variable, namely incomes policies.

The credibility of government policies has been widely recognized as a key element in successful stabilization programs [see, *e.g.*, Sargent (1986)]. A number of papers in the theoretical literature [for example, Barro and Gordon (1983), Backus and Driffill (1985), Dornbusch (1991), and Drazen and Masson (1994)] have attempted to formalize the concept of credibility in the context of policy games. In contrast, this paper examines the issue of credibility and government signaling from an econometric perspective. The agents' inferences about the true inflation regime are based on *actual* observations of the economic variables. Specifically, the model is estimated and tested using data from the Argentine and Israeli high inflation periods.

Related research in the empirical literature include papers by Ruge-Murcia (1995) and Kaminsky (1993) [see also Kaminsky and Lewis (1996)]. These authors also consider regime-switching models where agents produce inferences based on observed data. Ruge-Murcia allows agents to exploit the structural relationship between inflation and government expenditure to refine their estimates. In

Kaminsky, agents have access to additional information about the monetary stand of the Federal Reserve to imperfectly discriminate the sample [Lee and Porter (1984)]. In contrast, this paper models government signaling by means of a fully-specified, observable state and postulates that from the agents' perspective there is a qualitative and quantitative distinction if a reduction in the rate of inflation is indeed the result of reformed fundamentals or simply the consequence of price controls. The difference is captured by the inflation specification that allows income policies to directly affect the mean and variance of the series and stipulates idiosyncratic transition probabilities in and out of regimes with price controls. Furthermore, the assumption that announcements are observable by agents allows the econometrician to empirically isolate their signalling effect as manifested in the agents' money demand decision.

The plan of the paper is as follows. Section 2 presents a brief overview of the main elements of heterodox stabilization programs and their application in Argentina and Israel. Section 3 develops a model of money demand, introduces the time-series process of the rate of inflation, and describes the informational structure and the agents' inference problem. Section 4 discuses estimation issues and presents the main empirical results. Section 5 employs impulse-response analysis to examines the effect of different inference rules, probabilities of success of the stabilization, and the permanent/transitory nature of government signaling on money demand. Finally, Section 6 presents a brief discussion and the main conclusions of this research project.

2. Heterodox Inflation Stabilization

Several countries (*e.g*, Argentina, Brazil, Mexico, and Israel) experienced persistent and increasing rates of inflation during the 1980s. These episodes differed from the European hyperinflations in the 1920s in that the monthly rate of inflation was sufficiently small that prices continued to be set in local currency and there remained a significant volume of nominal contracts supported by the widespread use of formal and informal indexation. It was claimed at the time that the inflationary process contained an important inertial component as a result of staggered price setting [Blanchard (1983)], staggered long-term contracts [Fischer (1977), Taylor (1979)], backward-looking indexation [Fischer (1983)], and monetary accommodation by the Central Bank. It was argued that in these circumstances the use of tight fiscal and monetary policies to reduce the inflation rate would lead to high, politically infeasible losses of output and employment [see Kiguel and Liviatan (1989)].

Given the characteristics of the inflation process and political constraints, a new strategy was proposed aimed at reducing the rate of inflation without the associated disinflation costs. This approach, referred to as "heterodox", was based on the following elements:[1]

(*i*) Prior to the implementation of the program, the government made discrete adjustments in the exchange rate, public-sector tariffs, wages, and the price of subsidized commodities in order to correct distortions in relative prices. Then, nominal variables were frozen temporarily through administrative controls.

(*ii*) The government announced a commitment to reduce the size of the budget deficit and its monetization by the Central Bank. The fulfillment of these assurances would correct the underlying causes of inflation and would set in place the "fundamentals" required to sustain a lower inflation rate.

(*iii*) Monetary reform was undertaken with the introduction of a new currency pegged to the US Dollar.

(*iv*) Existing indexation contracts were temporarily abolished.

The basic difference between this heterodox approach and orthodox stabilization is that the latter relies solely on restrictive fiscal and monetary policies to reduce the rate of inflation while the former also involves the temporary use of incomes policies. More precisely, the regime of controlled prices and wages is supposed to *signal* the switch to a new lower inflation rate that in theory will be supported by changes in monetary and fiscal policies implemented during this period.

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[1] Helpman and Leiderman (1988) provide a discussion of the analytical basis for heterodox stabilization programs.

The application of these policies in Israel and Argentina produced different results. The Israeli stabilization plan, launched in July 1985, was successful. It reduced the average monthly inflation rate from 14% in the second quarter of 1985 to 1% in the first quarter of 1986 with a small increase in the rate of unemployment. Inflation remained stable when price controls were removed in early 1986. On the other hand, the stabilization program implemented in Argentina (June 1985) showed early signs of success, but inflation resumed after price and wage controls were lifted. Subsequent heterodox plans were tried again in the late 1980s without success. The monthly rates of inflation in Argentina and Israel are presented in Figures 1 and 2, respectively, with the periods when incomes policies were in effect denoted between bars.

3. A Model of Money Demand Subject to Changes in Regime

Consider an economy where the agents' demand for real balances is described by a Cagan money demand function.[2] Formally,

$$m_t - p_t = cy_t - \alpha i_t + \zeta_t , \qquad \alpha, c > 0. \tag{1}$$

where m_t, p_t and y_t denote (respectively) the natural logarithms of money, price level, and real income, i_t is the nominal interest rate, and the coefficients c and α denote (respectively) the semi-elasticities of money demand with respect to income and the rate of interest. As in preceding literature [*e.g.*, Sargent and Wallace (1973), Salemi and Sargent (1979), Flood and Garber (1980), Burmeister and Wall (1982, 1987), LaHaye (1985), and Casella (1989)], the disturbance term ζ_t is conveniently assumed to follow a random walk. That is, $\zeta_t = \zeta_{t-1} + e_t$, where e_t is an identically and independently distributed (*i.i.d*) random shock with zero mean and variance σ_e^2. The nominal interest rate in equation (1) measures the opportunity cost of holding money rather than (nominal) bonds and is determined by the Fisher equation,

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[2] Although it is not done explicitly here, this type of money demand function can be easily motivated from utility maximization [see, *e.g.*, Kingston (1982), Gray (1984), and Obstfeld and Rogoff (1985)].

$$i_t = r_t + E(\pi_{t+1}|I_t) \ , \tag{2}$$

where r_t is the *ex-ante* real interest rate, I_t is the non-decreasing set of information available to agents at time t, and $E(\pi_{t+1}|I_t)$ is the conditional expectation of inflation at time t+1. It is assumed that while past statistics on all economic variables are freely available, current information is infinitely costly. Thus, the agents' information set at time t includes all previous, but not current, observations of inflation and the growth rate of money.[3]

With (2) into (1) and first-differencing,

$$\mu_t - \pi_t = c(y_t - y_{t-1}) + \alpha[E(\pi_t|I_{t-1}) - E(\pi_{t+1}|I_t)] - \alpha(r_t - r_{t-1}) + e_t \ , \tag{3}$$

where μ_t is the rate of growth of money at time t. Equation (3) is simplified by means of two assumptions. First, real income is postulated to grow at a constant rate (denoted by g). This premise merely reflects the relative stability of income growth when compared with the large fluctuations in the inflation rate and real balances during the period considered. Second, the change in the *ex-ante* real interest rate is modeled as a white noise [see Rose (1988)].[4] In other words, $r_t - r_{t-1} = v_t$, where v_t is a serially uncorrelated disturbance with zero mean and variance denoted by σ_v^2. Therefore, equation (3) can be rewritten as,

$$\mu_t - \pi_t = n + \alpha[E(\pi_t|I_{t-1}) - E(\pi_{t+1}|I_t)] + u_t \ , \tag{4}$$

where $n = cg$ and the parameter α is reinterpreted as the semi-elasticity of money demand with respect to the rate of inflation. The composite error term, $u_t = e_t - \alpha v_t$, satisfies $E(u_t) = 0$ and $E(u_t u_j) = 0$ for all $t \neq j$, and

has a constant variance denoted by σ_u^2.

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[3] A natural interpretation of this assumption is that data-processing and publication lags make infeasible for agents to contemporaneously observe aggregate data.

[4] Rose presents empirical evidence on the presence of a unit root in the *ex-ante* real interest rate for various countries and sample periods. While his finding does not necessarily imply that the root is exactly one, it seems reasonable to suppose that the contribution to the disturbance term arising from deviations of the assumed random walk is quantitatively small compared with the other components of the error term.

3.1. *Time Series Specification for the Rate of Inflation*

As documented in Figures 1 and 2, the series of inflation exhibit a markedly different behavior in different time periods. Possible sources of this heterogeneity are (*i*) changes in the fiscal and monetary policies followed by the government, (*ii*) the direct effect of price controls on the measured rate of inflation, and (*iii*) the simultaneous effect of both (*i*) and (*ii*). Accordingly, I postulate a time series process for the inflation rate that explicitly allows for shifts in the mean and variance of the series arising from the effect of alternative government policies. More precisely, inflation is assumed to follow a stationary, autoregressive process subject to discrete regime changes [Hamilton (1989)] of the form,

$$\pi_t = \beta_{s(t)} + \phi_1 \pi_{t-1} + \phi_2 \pi_{t-2} + \ldots + \phi_q \pi_{t-q} + \sigma_{s(t)} \varepsilon_t \, , \tag{5}$$

where $s(t)$ denotes the inflation regime at time t, $\sigma_{s(t)}$ and $\beta_{s(t)}$ are variables whose value depends on the inflation state at time t, ϕ_i for $i = 1, 2, \ldots, q$ are constant coefficients, and ε_t is a serially uncorrelated disturbance term with zero mean, variance equal to 1, and possibly (contemporaneously) correlated with u_t.[5] The regimes or states are described by the possible combination of the two policy tools employed by the government to affect the rate of inflation, namely changes in fiscal and monetary policies and the use of administrative price controls. The four possible regimes are then defined as follows,

state 1 = low inflation and *no* signaling,

state 2 = low inflation and signaling,

state 3 = high inflation and *no* signaling,

state 4 = high inflation and signaling.

A low inflation regime is interpreted as the state when the government has successfully reformed the underlying fundamentals of the inflation process. A high inflation regime refers to the situation when

[5] I also considered more general specifications in which (in addition to β and σ) the autoregressive coefficients were modeled as state-dependent. However, after performing the appropriate Likelihood Ratio (LR) tests, I was unable to reject the null hypothesis of constant autoregressive coefficients. The (joint) statistical significance of lags of money growth was also tested. Results suggested that the univariate specification (5) suitably describes the inflation rate process for the countries under consideration.

fundamentals remain at a higher level than is consistent with the inflation target. A regime with signal denotes the case where the government signals its change in fiscal and monetary stands by means of incomes policies. Finally, a regime with no signal describes the situation when price controls are not currently in effect.

The process for $s(t)$ is assumed to depend on past realizations of π and s only through $s(t\text{-}1)$. The evolution of the state variable is characterized by a Markov chain with matrix of transition probabilities

$$\boldsymbol{P} = \begin{pmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \\ p_{41} & p_{42} & p_{43} & p_{44} \end{pmatrix}, \tag{6}$$

where $p_{ij} = Pr(s_t = j|s_{t\text{-}1} = i)$, and

$$\sum_{j=1}^{4} p_{ij} = 1, \qquad \text{for i} = 1,2,3,4.$$

In theory, it would possible to parameterize the transition probabilities as a (non-linear) function of predetermined variables [see Diebold *et. al.* (1994) and Filardo (1994)]. For example, parameterizing the probabilities as a function of lagged inflation would alter the likelihood of the government’s modifying its policies in light of increasing rates of inflation. However, notice that these specifications would substantially complicate the estimation of the model. Specifically, it would be necessary to numerically calculate the conditional expectation of a non-linear function of endogenous and/or exogenous variables for every observation in the sample. Thus, in order to keep the scope of this project manageable, the elements of the matrix ***P*** are assumed to be time-invariant.

The non-linear specification (5) for the inflation rate is attractive, among other reasons, because it accords well with recent theoretical research on recurrent hyperinflations [*e.g.,* Mondino, Sturzenegger, and Tommasi (1996), Marcet and Nicolini (1996), and Zarazaga (1996)], intuitively describes the changes in mean and variance observed in the inflation rate as resulting from the effect of different government actions, and replicates in a tractable manner the agents' uncertainty about the true nature of government policy.

3.2. *The Agents' Inference Problem*

In making their money demand decision, agents are compelled to make an assessment about current (and future) government policy as manifested in the inflation regime. Recall that as part of their portfolio choice, agents need to produce a forecast of the rate of inflation next period. Since the regime generating the future observation of inflation depends on the current state, agents need to construct an inference about the current inflation regime. If agents observe the state variable without error, then their inference problem is trivial. On the other hand, if agents are unable to observe the regime, then the optimal solution to their signal extraction problem involves the construction of probability estimates about the inflation state.

For this project, it is assumed that agents are unable to directly observe the nature of the fiscal and monetary policies pursued by the government (*i.e.,* whether they are indeed consistent with a low rate of inflation or not) but they are able to observe whether the government has implemented incomes policies as part of a stabilization program. The premise that agents observe the government's signal follows from the fact that price controls are publicly announced and has the implication that agents can perfectly discriminate between states 1 and 3 (where price controls are absent) and states 2 and 4 (that do include price controls). For example, following the introduction of a heterodox stabilization program, agents understand that the observations of inflation are not generated by either state 1 or 3. However, they are unable to observe whether the government is truly following a low or high inflation policy and, consequently, whether the change in the rate of inflation is simply the result of price controls. In terms of the states defined above, agents must still infer whether the inflation observations are generated by either regime 2 or 4.

The informational structure above factually describes the nature of stabilization programs and allows government announcements to provide agents with additional (possibly truthful) information to refine their assessments about the inflation regime. Furthermore, it makes possible to empirically separate the signaling effect of announcements (summarized here by the introduction or lifting of price controls) through their effect on the agents' money demand decision. Notice that even though agents unambiguously observe the current government signal, as part their formation of inflation expectations, they still need to construct a forecast as to whether incomes policies will or will not be in effect in the following period. Thus, the possible future introduction or suspension of price controls is also allowed to explicitly affect current inflation and money demand.

Since rational agents use efficiently all available information, they form probability inferences on the basis of the joint process of inflation, money growth, and government announcements, rather than on observations of the rate of inflation alone. These probabilities provide the researcher with a concrete, well-defined variable that summarizes agents' beliefs. Thus, the credibility of the government's stabilization attempt could be measured in terms of the agents' inferred probabilities. If following the government's announcement of reform, agents assign a high probability to the event that the currently available observations of the economic variables are in effect generated by a low inflation regime, then the government's program would be deemed as credible. On the other hand, should the agents conclude that, despite government assurances, the joint process of inflation and money growth, is generated by a high inflation regime, then the government's stabilization program could not have been credible.

In order to formalize this concept of credibility, define the 2×1 vector $Z_{t-1} = [\mu_{t-1}\ \pi_{t-1}]'$ with the realized values of money growth and inflation. Recall that by definition the agents' information set at time t contains all past observations of the economic variables, that is, $\{Z_{t-1}, Z_{t-2}, Z_{t-3}, \ldots\} \in I_t$. In addition, I_t includes government announcements as to whether price controls are in effect or not. Construct the 1 × 4 vector

$$\boldsymbol{L}_{t\text{-}1} = [Pr(s(t\text{-}1) = 1|I_t) \quad Pr(s(t\text{-}1) = 2|I_t) \quad Pr(s(t\text{-}1) = 3|I_t) \quad Pr(s(t\text{-}1) = 4|I_t)],$$

with the probabilities that summarize the agents' beliefs about the regime. For example, $Pr(s(t\text{-}1) = 1|I_t)$ is the probability that agents assign at time t to the inflation rate having been in the low state 1 at time t-1, conditional on all observations of inflation, money growth, and government announcements up to t-1. Notice that since price controls is an observable binary variable, there are always two zero and two non-zero elements in $\boldsymbol{L}_{t\text{-}1}$. That is, if incomes policies are *not* in effect at time t-1, then $Pr(s(t\text{-}1) = 2|I_t)$ and $Pr(s(t\text{-}1) = 4|I_t)$ are both zero. On the other hand, if price controls are in effect at time t-1, then $Pr(s(t\text{-}1) = 1|I_t)$ and $Pr(s(t\text{-}1) = 3|I_t)$ are both zero. Since in a rational expectations model the probabilities inferred by agents correspond to the ones generated by the economic model, the researcher concludes that the government's program is credible to agents at time t, if

$$Pr(s(t\text{-}1) = 1|I_t) + Pr(s(t\text{-}1) = 2|I_t) \geq 0.5.$$

Conversely, if

$$Pr(s(t\text{-}1) = 3|I_t) + Pr(s(t\text{-}1) = 4|I_t) < 0.5,$$

the econometrician concludes that the stabilization program is not credible to agents at time t.

Notice that the probability inferences in $\boldsymbol{L}_t$ evolve over time as new observations of inflation, money growth and government announcements are incorporated to the agent's information set. Methodologically, agents are assumed to use Bayesian updating to continuously revise their assessments about government policy in light of the most recent observations of the pertinent variables.

Alternatively, one could assess the credibility of the government's stabilization program by calculating the probability that inflation will continue in the low inflation regime once income policies are lifted. I refer to this value as the "probability of success" of the stabilization and define it by

where the parameters p_{21}, p_{23}, and p_{24} are given by the elements in the second row of the matrix of

$$\Pr(\text{success}) = \frac{p_{21}}{p_{21} + p_{23} + p_{24}} \ ,$$

transition probabilities, $\boldsymbol{P}$ [see equation (6)]. A high value of Pr(success) is associated with a credible stabilization because it means that agents understand that during the period with administrative controls, the government has indeed modified the fundamentals of the inflation process to sustain the targeted inflation rate. Section 3.3. (below) shows how these two definitions of credibility are relevant for the agents' money demand decision.

3.3. *Solution of the Model*

The model solution consists of deriving the appropriate expressions for the conditional expectations of inflation in money growth equation (4) and writing the later in reduced form. To that effect, apply the operator $E(\cdot\,|I_{t-1})$ in both sides of (5) to obtain

$$E(\pi_t|I_{t-1}) = E(\beta_{s(t)}|I_{t-1}) + \phi_1 E(\pi_{t-1}|I_{t-1}) + \phi_2\pi_{t-2} + \ldots + \phi_q\pi_{t-q}, \tag{7}$$

where

$$E(\pi_{t-1}|I_{t-1}) = E(\beta_{s(t-1)}|I_{t-1}) + \phi_1\pi_{t-2} + \phi_2\pi_{t-3} + \ldots + \phi_q\pi_{t-(q+1)}. \tag{8}$$

Use the properties of the Markov-chain process and the assumption that agents obtain information with a one-period lag to write

$$E(\beta_{s(t+i)}|I_{t-1}) = \boldsymbol{L}_{t-2}\,\boldsymbol{P}^{\,i+2}\boldsymbol{B}, \tag{9}$$

where the 4 × 1 vector $\boldsymbol{B} = [\beta_1 \quad \beta_2 \quad \beta_3 \quad \beta_4]'$ contains all possible values that the state dependent constant $\beta_{s(t)}$ can take. With (8) and (9) into equation (7), the equivalent result for $E(\pi_{t+1}|I_t)$, and (5), it is straightforward to write the rate of money growth in reduced form as

$$\mu_t = n + \beta_{s(t)} + \Gamma_t + \lambda_1\pi_{t-1} + \ldots + \lambda_q\pi_{t-q} + \lambda_{q+1}\pi_{t-(q+1)} + \sigma_{s(t)}\varepsilon_t + u_t \ , \tag{10}$$

where the notation

$$\Gamma_t = -\alpha(\boldsymbol{L}_{t\text{-}1}\text{-}\boldsymbol{L}_{t\text{-}2})(\boldsymbol{P}+\phi_1\boldsymbol{I})\boldsymbol{B}, \tag{11}$$

represents a time-varying change-in-regime component and $\boldsymbol{I}$ is the 4 × 4 identity matrix. The coefficients of lagged inflation rate are subject to the non-linear cross-equation restriction imposed by the behavioral money demand function, namely,

$$\lambda_1 = \phi_1 - \alpha(\phi_1^2 + \phi_2),$$

$$\lambda_i = \phi_i - \alpha\phi_1^2(\phi_i - \phi_{i\text{-}1}) - \alpha(\phi_{i+1} - \phi_i), \qquad \text{for } i = 2, 3, \ldots, q\text{-}1,$$

$$\lambda_q = \phi_q - \alpha\phi_1^2(\phi_q - \phi_{q\text{-}1}) + \alpha\phi_q,$$

and,

$$\lambda_{q+1} = \alpha\phi_1^2\phi_q.$$

The specification of the inflation rate process and the functional form of the money demand imply that the rate of money growth depends on (*i*) the state dependent constant $\beta_{s(t)}$ that denotes the regime of the inflation process, (*ii*) past levels of inflation that partially determine the agents' forecast of future inflation, and (*iii*) the change-in-regime component, Γ_t. As explained below, this component arises from the agents' revision of the future path of inflation given new information become available between periods t-1 and t.

In order to develop some intuition, assume for a moment that agents know with certainty that the inflation state has switched from the high to the low regime at time t-1. That is, $s(t\text{-}2) = 3$ and $s(t\text{-}1) = 1$. Then, since $\alpha > 0$ and (by definition) $\beta_3 > \beta_1$, the change-in-regime component would take a positive value, meaning there is a once-and-for-all increase in the growth rate of money demand as agents expect this new, low inflation regime to remain in place for some time. This result intuitively describes the empirical observation [see *e.g.*, Sargent (1986) and Romer (1996, p. 428)] that following the end of a hyperinflation, real balances rise as a result of increase in *nominal* money demand rather than a decrease in the price level. Conversely, should the agents observe a change from the low to the high inflation regime, then this component would take a negative value (with the same magnitude). Finally, if the agents observe that no change in the process of π_t has taken place at time t-1, then this component would be exactly zero because $\mathbf{L}_{t-1} = \mathbf{L}_{t-2}$. In the present model, agents do not observe the state of the inflation process and, consequently, the value of the change-in-regime component is determined by the relative magnitude of the probabilities agents associate to each of the regimes. Notice that in this case, the size of the component is not limited to the finite number of values that it can take under certainty, and its contribution varies throughout the sample as agents' revise their inferences about government policy in every period.

The magnitude of Γ_t also depends on the (relative) size of the elements of the transition matrix $\boldsymbol{P}$. While it is not possible to characterize this dependence analytically, one would expect that the agents' willingness to raise their money holdings is an increasing function of the persistence of the low inflation regime(s) and the probability of success of the stabilization program. Section 5 will examine this issue by means of impulse-response analysis.

Finally, an important feature of the model is that the agents' response to changes in government policy are state-dependent and asymmetric. To see this, recall that in the case when inflation follows a standard ARIMA process, the agents' revision about the future path of inflation is history-independent and exactly proportional to the size of the current innovation. These properties follow solely from the linearity of the ARIMA process [see Koop, Pesaran, and Potter (1994)]. In contrast, the non-liner specification postulated here for the rate of inflation allows this revision to depend on the particular policy in effect when the innovation takes place, and permits more-than-proportional movements in money demand as a result of observed shifts in the inflation regime.

4. Estimation and Empirical Results

The model consists of the joint system of inflation and the associated solution for the rate of money growth. For convenience these equations are reproduced below,

$$\pi_t = \beta_{s(t)} + \phi_1\pi_{t-1} + \phi_2\pi_{t-2} + \ldots + \phi_q\pi_{t-q} + \sigma_{s(t)}\varepsilon_t \,, \tag{5}$$

$$\mu_t = n + \beta_{s(t)} + \Gamma_t + \lambda_1\pi_{t-1} + \ldots + \lambda_q\pi_{t-q} + \lambda_{q+1}\pi_{t-(q+1)} + \sigma_{s(t)}\varepsilon_t + u_t \,. \tag{10}$$

The state-dependent, variance-covariance matrix of the disturbances is,

$$\Omega_{\boldsymbol{s(t)}} = \begin{bmatrix} \sigma^2_{s(t)} & \sigma^2_{s(t)} + \sigma_{s(t)}\rho_{\varepsilon u}\sigma_u \\ \sigma^2_{s(t)} + \sigma_{s(t)}\rho_{\varepsilon u}\sigma_u & \sigma^2_{s(t)} + 2\sigma_{s(t)}\rho_{\varepsilon u}\sigma_u + \sigma^2_u \end{bmatrix}, \tag{12}$$

where $\sigma_{\varepsilon u}$ has been replaced by $\rho_{\varepsilon u}\sigma_u\sigma_\varepsilon$, $\sigma_\varepsilon = 1$ (by definition), and $\rho_{\varepsilon u}$ denotes the correlation coefficient of ε_t and u_t.

The problem of simultaneous equation bias that could arise in the estimation of money demand (1) is avoided here by postulating a specific time-series process for the rate of inflation and writing the system in reduced form. Since the model solution imposes cross-equation restrictions on the joint process of inflation and money growth, structural parameters are readily identified and the model itself can be tested using standard procedures.

Since the model involves a discrete unobserved state variable, its estimation requires the version of the Kalman filter developed by Hamilton (1989). In this case, where the state variable $s(t)$ is discrete, the shocks that drive its stochastic process are not normally distributed as $s(t)$ can only take a finite number of values. Thus, the standard Kalman filter does not generate optimal forecasts or evaluation of the likelihood function.[6] The recursive non-linear procedure proposed by Hamilton allows the estimation of structural parameters through the maximization of the likelihood function and generates probability assessments that the system was in a given regime for each observation in the sample. For more details, the interested reader is referred to Hamilton (1994, ch. 22).

Note that, by construction, the filter probabilities generated by the procedure constitute the

[6] However the Kalman filter would still provide the "best" predictor and updated estimator among the class of *linear* procedures [see Harvey (1988, p. 102)].

elements of the vectors $\mathbf{L}_{t-1}$ and $\mathbf{L}_{t-2}$ that form part of the model solution. Since in a rational expectations model, the probabilities perceived by agents correspond to the ones generated by the economic model, these filter probabilities can be employed by the econometrician to summarize the agents' beliefs about the inflation regime. Thus, an important feature of the specification composed of equations (5) and (10) is that it allows the explicit feedback from agents' inferences about government policy into the current value of the endogenous variables.

4.1. *The Data*

The model was estimated for Argentina and Israel using monthly observations of the rates of inflation and money growth. The inflation rates were taken from the *Monthly Bulletin of Statistics* published by the United Nations. The rates of money growth were measured by the percentage change of M1 using raw data from *Annual Report* of the Bank of Israel and the series 3F140 (Recursos Monetarios - M1) graciously provided by the Fundación de Investigaciones Económicas Latinoamericanas (FIEL). For Argentina, the sample period is January 1980 to April 1989 and its last observation immediately precedes the elections won by the Peronist Party. For Israel, the sample period was chosen to make results comparable with those of Ruge-Murcia (1995) and extends from January 1982 to December 1987.

For each country, a time-series with the periods when incomes policies were in effect was constructed by the author based on historical accounts. For Argentina these months are June 1985 to April 1986 (Austral Plan), March to May 1987 (February Plan), October to December 1987 (Austral Plan II), and August 1988 to February 1989 (Spring Plan). These four stabilization programs were introduced on 14 June 1985, 25 February 1987, mid-October 1987, and early August 1988, respectively. The incomes policies associated with the Austral Plan were lifted in April 1986 when the price freeze was replaced with a system of "administered" prices, public sector tariffs were raised by 6%, and nominal wages were allowed to be adjusted within a preset band [Machinea and Fanelli (1988, p. 142)]. The wage policy as part of the February Plan was modified after the appointment of a new Labor minister. Specifically, a 6% wage increase was decreed on 9 May 1987 (to be effective 1 June), and price controls were made more flexible in June [Kiguel (1989, pp. 25-26)]. The incomes policies related to the Austral II and Spring Plans started to be lifted in January 1988 and February 1989, respectively [*Latin American Regional Reports: Southern Cone Report*, 4 February 1988 and 12 March 1989].

For Israel, price controls were in effect from November 1984 to January 1985,[7] and from July 1985 to March 1986. Since March 1986, administered controls remained in effect for only 40% of all goods and services [Bruno and Piterman (1988, p. 11)].[8]

4.2. *Estimates of the Inflation Rate Process*

Initially, the appropriate lag length for the inflation process [equation (5)] was determined. Processes with lag length q = 1 through 6 were considered. After applying a battery of Likelihood Ratio (LR) tests, results indicated that the inflation rates of Argentina and Israel were most parsimoniously described by AR(1) and AR(3) specifications, respectively. Then, the parameters of the joint process of inflation and money growth were estimated by the numerical maximization of the log-likelihood function using the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm provided by GAUSS 3.0. Throughout the maximization procedure the constraints $p_{i1} + p_{i2} + p_{i3} + p_{i4} = 1$ for i = 1, 2, 3, 4, $0 < p_{ij} < 1$ for i, j = 1, 2, 3, 4, and $-1 < \rho_{\varepsilon u} < 1$ were imposed. Recall that p_{ij} denotes the transition probability between states i and j, and $\rho_{\varepsilon u}$ represents the correlation coefficient of the disturbances u_t and ε_t. As seen in Section 4.4, some of the Maximum Likelihood (ML) estimates fell on the boundary $p_{ij} = 0$. In order to compute

[7] In November 1984 a package deal was agreed between the government, the General Federation of Labor (Histadrut), and the employers' organizations. Under this plan, wages would be frozen temporarily and firms would limit price increases.

[8] Typically, the prices of 25% of available products in Israel are subject to some form of governmental control. This percentage rose to 90% at the onset of the stabilization program.

standard errors, I imposed p_{ij} = 0 and treated these parameters as known constants for calculating second derivatives of the log-likelihood function . In order to start the filter, the probability associated with the first observation was estimated rather than being assigned its unconditional value.[9] Finally, for the case of Israel, where the number of periods with price controls are limited, the restrictions $\sigma_1 = \sigma_2$ and $\sigma_3 = \sigma_4$ were also imposed. These testable restrictions imply that the volatility of the inflation rate is fundamentally determined by its level rather than by the effect of the government's incomes policies. More than one hundred randomly chosen starting values were used for each data set. The values of the parameters corresponding to the global maxima are reported.

For Argentina, the rate of inflation is

$$\pi_t = \beta_{s(t)} + \underset{(0.09)}{0.45}\pi_{t-1} + \sigma_{s(t)}\varepsilon_t \ ,$$

where estimates of the state-dependent components, $\hat{\beta}_{s(t)}$ and $\hat{\sigma}_{s(t)}$, are presented in Table 1. Under the assumption of stationarity, the *conditional* means of the inflation rate can be calculated by $\hat{\beta}_{s(t)}/(1 - \hat{\phi}_1)$ for $s(t)$ = 1, 2, 3, 4. Thus, regimes 1 through 4 are characterized by average inflation rates of 6.28, 4.35, 16.86, and 29.97 per month, respectively. These results show a substantial difference between the mean inflation in the low and high regimes (*i.e.*, states 1 and 3). A change in the inflation regime from state 3 to 1 would be associated with an immediate reduction of $\hat{\beta}_3 - \hat{\beta}_1$ = 5.82 (0.97) in the rate of inflation. In the long term, inflation would decline by $(\hat{\beta}_3 - \hat{\beta}_1)/(1 - \hat{\phi}_1)$ = 10.58 percent per month.[10] Since this regime switch does not involve the use of price controls, this inflation path could be associated with the one obtained by means of an orthodox stabilization program. The impulse-response generated by this

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[9] Notice that in this case, the use of unconditional probabilities to start the filter is inefficient because they do not use the information of whether price controls are or are not in effect for the first data point.

[10] While the difference between $\hat{\beta}_3$ and $\hat{\beta}_1$ is economically meaningful, its statistical significance cannot not be evaluated by means of the usual *t*-statistic. As it is well known, under the null hypothesis of linearity, the corresponding elements in the matrix of transition probabilities, ***P***, are not identified and standard inference theory does not apply. Some tests of the model will be presented below.

regime change is presented in Figure 3.

Notice that there is only a small numerical difference between the inflation mean in states 1 and 2 (6.28 - 4.35 = 1.93 percent per month). This result has the appealing interpretation that the equilibrium rate of inflation in the low regime is independent of the government's announcements of price and wage controls. Consider now a transition between states 3 and 2. Since this regime switch involves the use of income policies, the inflation path could be associated with the one observed after a heterodox stabilization program. One would expect, given the similarities between states 1 and 2, that this transition would be analogous to the one described above for a change in regime between states 3 and 1. Put differently, the transition between the high- and the low-inflation regimes would be independent of whether the government actively signals its new policy by means of price controls. In effect, inflation would be reduced by $\hat{\beta}_3 - \hat{\beta}_2 = 6.88$ (1.11) per month immediately and by 12.50 percent per month in the long run. However, as seen in Figure 3, the transition dynamics of the two stabilization strategies might be substantially different because (*i*) the agents' beliefs about the inflation regime can be affected by the government's signal and (*ii*) the transition between states 3 and 2 has always as intermediate step a one-period observation in state 4.

Regime 4 features the highest inflation mean among the four possible states. This result reflects the fact that several prices are adjusted by the government concurrently with the imposition of administrative controls, and that firms might have correctly anticipated the subsequent introduction of incomes policies and risen their prices immediately prior to their imposition.[11]

Regarding the state-dependent standard deviations, a LR test was employed to evaluate whether their difference is statistically significant. Since the restriction $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4$ is strongly rejected by the data (the *p*-value is well below 0.1 percent), it seems reasonable to conclude that inflation is indeed

[11] Kiguel and Liviatan (1990, p. 34) report that large increases in wholesale prices were observed in Argentina prior to each of the major price freezes (most notably in June 1985, October 1989, and June to August 1988).

more variable in the high- than in the low- inflation regimes.

Results for Israel are qualitatively similar to those obtained for Argentina. The rate of inflation is,

$$\pi_t = \beta_{s(t)} + \underset{(0.04)}{0.05}\pi_{t\text{-}1} + \underset{(0.04)}{0.06}\pi_{t\text{-}2} + \underset{(0.03)}{0.09}\pi_{t\text{-}3} + \sigma_{s(t)}\varepsilon_t \, ,$$

where the estimates of $\beta_{s(t)}$ and $\sigma_{s(t)}$ for $s(t)$ = 1, 2, 3, 4, can be found in the third column of Table 1. The mean rates of inflation in regimes 1 through 4 are calculated to be 1.49, 1.06, 10.79, and 23.40 per month, respectively. Thus, as in the case above, there is a significant difference between the inflation process in the low- and high-inflation regimes. In particular, states 3 and 4 feature larger and more variable rates of inflation than regimes 1 and 2.

Notice that a transition between states 3 and 1 would be associated with an immediate reduction in the rate of inflation of $\hat{\beta}_3 - \hat{\beta}_1$ = 7.44 (0.89) per month. In the long run, inflation would fall by 9.30 percent per month. Similarly, a regime switch between states 3 and 2, would be characterized by an immediate reduction of $\hat{\beta}_3 - \hat{\beta}_2$ = 7.78 (0.44) and a long term reduction of 9.72 percent per month in the inflation rate. While the short and long term effect of these two regime changes appear similar, the impulse-responses in Figure 4 document the fact that in practice their short-run dynamics could be substantially different. As above, this result might be due to the effect on inflation of price adjustments immediately prior to the introduction of incomes policies and price increases by private agents in anticipation to such policies. There is only a small numerical difference between the inflation means in states 1 and 2 (1.49 - 1.06 = 0.43 per month) and a LR test of the restriction $\sigma_1 = \sigma_2$ indicates that it cannot be rejected at the 1% or 5% significance levels (p-value ≈ 0.06).[12] Thus, the equilibrium rate of inflation in the low regime appears to be independent of announcements of price and wage controls.

[12] However, notice that this restriction would be rejected at the 10% significance level. The estimation of the model allowing for different values of σ in states 1 and 2 yielded analogous but less efficient results than the ones reported here and are available from the author upon request.

This result might explain the observation that for the case of Israel, incomes policies as part of the July 1985 stabilization seemed not to have been binding [Bruno and Piterman (1988, p. 11)].

Since a model with constant standard deviations is nested within the specification that allows them to be state-dependent, it is straightforward to test the restriction $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4$ by means of a LR test. The LR statistic of 79.6 that is well above the 1% critical value of 6.64 for a χ^2 variate with 1 degree of freedom. Thus, it is reasonable to conclude that inflation is more variable in the high- than in the low-inflation regime. Quantitatively, inflation volatility (as measured by its standard deviation) is approximately five times larger in the high-inflation regime than in the low-inflation state. This result (also confirmed for Argentina above) provides econometric evidence in favor of Friedman's (1977) conjecture of the joint feedback between the conditional mean and the variance of inflation [on this see also, Baillie *et al.* (1996)].

4.3. *Estimates of the Money Growth Process*

For Argentina, the growth rate of money is described by

$$\mu_t = \underset{(0.80)}{-\,2.31} + \beta_{s(t)} + \Gamma_t + 0.24\pi_{t-1} + 0.22\pi_{t-2} + \sigma_{s(t)}\varepsilon_t + u_t \ ,$$

where, due to the model restrictions, the state-dependent components take the same numerical values as in the inflation equation [see Table 1]. Estimates of the standard deviation of the money demand shock, u_t, and its correlation with the inflation disturbance, ε_t, are (respectively) $\hat{\sigma}_u = 8.42$ (0.58) and $\hat{\rho}_{\varepsilon u} = -0.41$ (0.08). The bracketed figures denote standard errors. The fact that $\hat{\rho}_{\varepsilon u}$ is negative simply indicates that an unexpected *increase* in inflation would contemporaneously *decrease* the growth rate of money demand.

Let us now examine the effect of the change-in-regime component, Γ_t, on the money growth process. This component captures the dynamic nature of agents' inferences about the inflation state and evolves over time as agents incorporate additional observations to their information set. Note in Figure

5 that Γ_t is stable and close to zero for most of the sample but features occasional positive and negative spikes. The fact that this variable is close to zero merely indicates that, after revising their inferences about the inflation regime, agents assign a high probability to the inflation process being the same state as in the previous period (that is, $\Pr(s(t) = j|I_t) \approx \Pr(s(t\text{-}1) = j|I_{t-1})$). On the other hand, the spikes in Γ_t are associated with specific economic events and in a transparent manner describe the agents' portfolio adjustment in light of perceived changes in government policy. More precisely, the three large positive spikes are associated with the reduction in inflation following the stabilization programs in June 1985, October 1987, and August 1988. In these cases, the change-in-regime component is positive because the growth rate of money demand is larger than usual while agents increase their real balances. As noted above, this result characterizes the empirical observation that following the end of a high inflation period, real balances rise as a result of an increase in *nominal* money demand rather than a reduction in the price level. As explained in Section 5, this effect takes place *even* if the change in the inflation process is inferred to be temporary, but its magnitude increases with the persistence of the low-inflation regime. Similarly, the four large negative spikes are related to the perceived change in inflation regime around June 1982, and the abandonment of stabilization in programs in July 1987, February 1988, and April 1989.

For Israel, the rate of money growth is

$$\mu_t = \underset{(0.91)}{-\,0.35} + \beta_{s(t)} + \Gamma_t - 0.02\pi_{t-1} + 0.02\pi_{t-2} + 0.19\pi_{t-3} + 0.004\pi_{t-4} + \sigma_{s(t)}\varepsilon_t + u_t\ ,$$

where the estimate of the standard deviation of the money demand disturbance is $\hat{\sigma}_u$ = 8.24 (0.66) and the correlation coefficient of u_t and ε_t is $\hat{\rho}_{\varepsilon u}$ = -0.37 (0.11). Notice that $\rho_{\varepsilon u}$ is negative (as expected) and statistically different from zero.

The change-in-regime component for Israel is presented in Figure 6. Notice that Γ_t features two large positive spikes associated with the stabilization programs in November 1984 and July 1985. The large negative spike in March 1985 is related to the agents' portfolio adjustment following the failure the stabilization program of November 1984. It is interesting to notice that Γ_t also fluctuates considerably in the period immediately after the lifting of price controls in March 1986. As mentioned above, this component embodies the agents' revision of their assessments about government policy and their uncertainty about the true regime generating the joint process of inflation and money growth. It is apparent from Figure 6, that agents' uncertainty about the nature of the inflation process was heightened by the removal of income policies in early 1986.

The estimates of the semi-elasticity of money demand, α, for Argentina and Israel are 1.06 (0.35) and 1.04 (0.68), respectively. These values have the expected positive sign, are significantly different from zero, and accord well with econometric estimates obtained by earlier researchers. For example, Frenkel (1977) estimates α = 2.144 (0.325) for the German hyperinflation, La Haye (1985) finds values ranging from 0.58 (Greece) to 2.66 (Poland), Cagan (1956) obtains estimates between 2.3 and 8.7 for the hyperinflationary periods in Poland and Hungary, respectively, and Barro (1970) estimates values for α between 2.56 (Poland) and 5.53 (Hungary).

4.4. *Specification Testing*

In addition to the statistical tests presented above, a joint LR test of all the cross-equation restrictions imposed by the model on the process of inflation and money growth was performed. The alternative hypothesis was designed to include the null hypothesis as a nested, special case. The estimated LR statistics for Israel and Argentina were (respectively) 21.49 and 12.40. Under the null hypothesis, these variables are distributed χ^2_9 and χ^2_7 where the subscripts denote degrees of freedom. Comparing the statistics and their relevant distribution indicates that the model restrictions cannot be rejected for either country at the 1% significance level (the associated *p*-values are 0.011 and 0.13 for Israel and Argentina, respectively).

As noted by Sims (1980, p. 17), the LR test can be biased against the null hypothesis in small samples. Thus, Sims proposes adjusting the test statistic by the factor $(T - k)/T$, where T is the sample size and k is the number of parameters estimated in the unrestricted system divided by the number of equations. Multiplying twice the difference in the value of the log-likelihood function by $(T - k)/T$ yielded Sims-adjusted LR statistics of 16.91 and 10.57 for Israel and Argentina, respectively. For this computation, the pair (T, k) was (84, 17.5) for Israel and (112, 16.5) for Argentina. In this case, the model restrictions cannot be rejected for either country at the 5%. In light of these results, I conclude that for the economic specification developed in Section 3 reliably describes the dynamic properties of the joint process of inflation and money growth.[13]

4.5. *Estimates of the Matrix of Transition Probabilities*

The estimated matrices of transition probabilities are important because they provide us with a statistical description of government policy. Specifically, they characterize the likelihood of the government pursing a change in policy regime in light of the current state and, consequently, affect the agents' portfolio decision. For Argentina and Israel, the estimates are (respectively),

$$\boldsymbol{P} = \begin{pmatrix} 0.936 & 0.026 & 0.038 & 0 \\ 0.064 & 0.794 & 0.142 & 0 \\ 0.004 & 0 & 0.935 & 0.061 \\ 0 & 1 & 0 & 0 \end{pmatrix}, \tag{13}$$

and

These results indicate that states 1, 2, and 3 are fairly persistent. Under the Markov process driving the state variable, $s(t)$, the expected duration of regime j is given by $1/(1 - p_{jj})$. Thus, on average, governments allow a high-inflation regime to continue for $1/(1 - 0.935) \approx 15$ months (Argentina) to 1/(1 -

[13] Notice that since the associated p-values are (respectively) 0.051 and 0.26 for Israel and Argentina, the inability of reject the null hypothesis for the former at the 5% level is only marginal.

$$
\boldsymbol{P} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0.090 & 0.799 & 0.111 & 0 \\ 0 & 0 & 0.945 & 0.055 \\ 0 & 1 & 0 & 0 \end{pmatrix} . \qquad (14)
$$

0.935) ≈ 18 months (Israel) before introducing a stabilization program. It is interesting to notice that for Israel, the low-inflation state 1 could be interpreted as an absorbing regime. Hence, agents understand that once a genuine reform has taken place, inflation will continue indefinitely in the low regime.

During the sample period consider, the high-inflation regime 3 is eventually followed by the state of high-inflation with government signaling (namely, $s(t) = 4$). In turn, this state is immediately followed by the low-inflation regime with signaling [$s(t) = 2$].[14] Incomes policies are typically maintained for 1/(1 - 0.794) ≈ 1/(1 - 0.799) ≈ 5 months in both countries.

Finally, it is possible to calculate the probability of success of the government's plan. This notion was defined above as the probability that the economy will continue in the low inflation regime [$s(t) = 1$] once price controls are lifted. Mathematically,

$$
\Pr(\text{success}) = \frac{p_{21}}{p_{21} + p_{23} + p_{24}} ,
$$

where the values p_{21}, p_{23}, and p_{24} can be read from (13) and (14) above. For the two countries under consideration the estimated values of Pr(success) are 0.064/(0.064 + 0.142 + 0) = 0.31 (0.25) for Argentina, and 0.09/(0.09 + 0.111 + 0) = 0.45 (0.33) for Israel. The figures in parenthesis denote estimated standard errors. While the point estimates of the probability of success are rather imprecise, it could be argued that these result support the view that the stabilization programs in Israel might have been more credible to economic agents than the ones implemented in Argentina. Section 5 will consider the

[14] Notice that since $p_{44} = 0$, the expected duration of regime 4 is only 1 period. Since $p_{42} = 1$, this regime is invariably followed by state 2.

effect of different values of Pr(success) on the agents' money demand decision.

4.6. *Agents' Inferred Probabilities of Reform*

Probability inferences about the inflation regimes for Argentina and Israel are presented in Figure 7 and 8, respectively. Each figure contains three graphs with the probabilities deduced by agents about regimes 1, 2 and 3. The probabilities for state 4 can be trivially derived from the other three by noting that the sum of all four probabilities should add up to one.

Notice that for Argentina, agents assign a high probability to inflation being in the low regime, $s(t) = 1$, until June 1982 (inclusive). The probability is larger than 0.70 for all observations before this date, except for January and February 1982, when they are respectively 0.27 and 0.40. The change in inflation regime in July 1982 is contemporaneous with the Argentinean defeat in the Falkland War, the suspension of new foreign lending, and the ensuing change in military government.[15] Thus, it seems plausible that this regime switch in the inflation process was the result of external and political factors that affected the country in this period.

Thereafter, agents assign a high probability to the economy being in the high-inflation regime until the introduction of the Austral Plan in mid-June 1986. Following a one-period observation of regime 4 in June 1985, agents correctly infer that the data of inflation and money growth are generated by the low inflation regime with price controls. The probabilities are exactly 1 for all data points until March 1986 (inclusive) when incomes policies were suspended. For the subsequent month (*i.e.*, April 1986), the probability that inflation is in the low regime $s(t) = 1$ is 0.79, but it rises quickly to 0.99 in the following months until early 1987.

After the introduction of the February Plan, agents assign a unit probability to the event that the

---

[15] Argentina surrendered to the British on 14 June 1982. President General Leopoldo Galtieri resigned and was replaced by General Reynaldo Bignone on 1 July [*Latin American Weekly Report*, 2 July 1982 (p. 7)].

variables were generated by regime 2 during the period March to May 1987 (inclusive). Interestingly, once price controls are lifted, agents infer an immediate switch to the high inflation regime $s(t) = 3$. The probabilities that the economy is in state 3 are 0.80, 0.93 and 0.99 in June, July and August 1987. Thus, it seem likely that for this program agents deduced that the reduction in the rate of inflation was solely the result of price controls and that no effective change in government's policies had actually taken place.

An analogous pattern is observed for the Austral II and Spring Plans. That is, after a brief, transitory reduction in inflation resulting from the effect of price controls, agents infer a reversion to the high inflation regime. Hence, following the removal of incomes policies in December 1987, the agent's inferred probability that inflation is in state 3 rises from 0.84 in January 1988 to 0.99 in March 88. Similarly, when the price controls associated with the Spring Plan are suspended in February 1989, agents assign a probability of 1 to the event that the data is generated by the high-inflation regime $s(t) = 3$.

For Israel, Figure 8 indicates that agents infer inflation is in the high state 3 until October 1984. Following the tripartite accord between the government, the Histadrut, and employers' organizations in November 1984, agents correctly deduce that inflation is in the low regime with price controls for the months of December 1984 and January 1985. However, after the end of this agreement, agent unequivocally infer an immediate return to the high-inflation regime. The probability that inflation is generated by state 3 rises to 1 in February 1985 and continues at this level until June 1985.

With the introduction a new program in July 1985 and following a one-period observation of regime 4 that month, agents conclude that the joint process of inflation and money growth is generated by the low-inflation regime with price controls [$s(t) = 2$]. The probabilities are exactly 1 for all observations until income policies are lifted in March 1986. In the following month (April 1986), the probability assigned by the agents to the event that inflation is in the low state 1 is only 0.48 but it rises to 0.95 and 0.997 May and June, respectively, as agents learn the new policy regime. From October 1986 and until the end-of-sample, the agents' inferred probability that inflation is in the low state $s(t) = 1$ is exactly 1.

The above results support two conclusions. First, the successful stabilization program implemented in Israel in July 1985 seem to have been more credible to the agents than either the earlier Israeli attempt in November 1984 or the later Argentine programs (February Plan, Austral II Plan, and Spring Plan). These results complement the conclusions in Section 4.5 and confirm earlier findings by Ruge-Murcia (1995). Second, the government's signaling by means of price controls might substantially simplify the agents' inference problem. To see this, notice that in the periods when agents must discriminate between inflation regimes without incomes policies (that is, $s(t) = 1$ and $s(t) = 3$), the probability estimates are more variable and seldom take the extreme values zero/one. On the other hand, when agent must discern between states 2 and 4, their probability inferences are more stable and usually take the polar values of zero or one. Hence, it might be argued that for the Austral Plan (Argentina) and the July 1985 Plan (Israel), the governments' signal might have reduced the learning period about the inflation regime on the part of the agents and promoted a faster transition to the new equilibrium.

5. The Effect of Credibility and Signaling on Money Demand

Recall that the change-in-regime component (Γ_t) that forms part of the model solution is thought to reflect the agents' willingness to promptly adjust their money holdings in light of inferred changes in government policy. In the specific case of a disinflation, Γ_t characterizes the agents' restocking of real balances as the expected rate of inflation decreases. By definition,

$$\Gamma_t = - \alpha(\boldsymbol{L}_{t-1}-\boldsymbol{L}_{t-2})(\boldsymbol{P}+\phi_1\boldsymbol{I})\boldsymbol{B},$$

where the 1×4 vector $\boldsymbol{L}_{t-i}$ for $i = 1, 2$, contains the agents' inferences about the four possible regimes based on information available up to time t-i, and $\boldsymbol{P}$ is the matrix of transition probabilities that rules the stochastic process of the state variable.

The dependence of Γ_t on $\boldsymbol{P}$ and on the agents' beliefs contained in $\boldsymbol{L}_t$ is examined in this section using impulse-response analysis. Specifically, the paths of $\boldsymbol{L}_{\mathbf{t}}$ under different inference rules, probabilities of success, and persistence of government signaling are considered. For the purpose of this exercise, I have used the parameter estimates for Israel.[16] For all impulse-response functions presented below, it is assumed that a true change in government policy has actually taken place.

5.1. *Inference Rules*

First, consider the path of Γ_t under three different inference rules. For this exercise, the components of **P** are kept equal to their ML estimates in (14). The resulting impulse-responses are presented in Figure 9 in three panels. The upper panel considers the case when inference is "perfect" in the sense that agents are able to unambiguously deduce the inflation regime. In this case, immediately following the stabilization program, agents increase their money holdings and the rate of growth of money is approximately 9 percentage points higher than otherwise. After price controls are lifted, agents correctly deduce that inflation continues in the low regime [$s(t)$ = 1] and further increase their money holdings.

The middle panel considers the case of skeptical agents that despite additional observations of low inflation assign a unitary probability to the event that inflation is in the high regime $s(t) = 3$. In this case, agents do not modify their portfolio choice and Γ_t is zero in all periods.

Finally, the lower panel considers the case of learning when agents employ currently available observations of inflation, money growth, and government announcements to construct inferences about the inflation regime. For this case, I have used the actual filter probabilities estimated for Israel during the period June 1985 to July 1986. As pointed out above, government signaling might simplify the agents' inference problem and, consequently, the initial path of Γ_t resembles the one under perfect inference. However, after signaling ends, agents must learn the current regime solely on the basis of

[16] The results obtained using estimates for Argentina are very similar to the ones presented below and are available from the author upon request.

available observations of inflation and money growth. For the case of Israel, the uncertainty about the true inflation after March 1986 and the subsequent learning that inflation was in the low regime are reflected in the substantial volatility of Γ_t in this period.

5.2. *Probability of Success*

The effect of the probability of success on the agent's money demand decision is examined in Figure 10. I have kept p_{22} and p_{24} equal to their ML estimates of 0.799 and 0, respectively, but employed different values of p_{21} and p_{23} to compute the probability of success. The path of the change-in-regime component for Pr(success) = 0.005, 0.448, and 0.995 are presented. These three figures share the feature that agents substantially increase their money holdings after the initial reduction in inflation. However, up the extent that the actual success of the plan is less or more expected, agents react differently to inflation continuing in the low regime after the end of the signaling regime. Specifically, agents that had assigned the lower Pr(success) would most strongly react to the new information. Nonetheless, in light of this results, it could be suggested that the expected probability of success of the government's plan might not significantly affect the agents' short-term portfolio choice. The following section will argue that this finding might be explained by the short-term welfare gains that accrue to the agents by temporarily increasing their real balances.

5.3. *Permanent and Transitory Signaling*

Since the expected duration of regime 2 is given by $1/(1 - p_{22})$, different values of p_{22} have associated different predictions as to the number of periods that government signaling will be in effect. In this section, I have kept constant the probability of success to its ML estimate of 0.448 and simulated the paths of Γ_t for different values of p_{22}. These results are presented in Figure 11.

First, consider the case $p_{22} = 0.999$ and the low inflation regime (with signaling) is expected to be (almost) permanent.[17] In this case, agents immediately replenish their money holdings and money growth is approximately 9 percentage points higher than otherwise. Interestingly, a similar profile is observed when p_{22} = 0.666 and price controls are expected to last only three months.

On the other hand, in the situation when p_{22} = 0 and the temporarily low inflation is expected to last only one period, agents increase their money holdings by a significantly lower magnitude than in the two earlier examples considered. This results suggest that, in the absence of transaction costs, the welfare gains from a temporary increase in real balances might be high enough to induce agents to raise their real balances in the short-term even if they are not certain about the true nature of government policy and the eventual outcome of the stabilization attempt.

6. Conclusions

This paper has developed a fully-specified model of money demand where the rate of inflation is subject to both announced and unannounced regime changes. The inflation specification (*i*) replicates the agents' uncertainty about the true nature of government policy and (*ii*) poses agents with a signal extraction problem that is optimally solved by their constructing probability estimates. These inferences are based on currently available information that includes the government signal embodied in announced price controls. This framework permits the analysis of the role of credibility and signalling in inflation stabilization by focusing on the agents' money demand decision.

The FIML estimates of the parameters and specification tests provide support for the restrictions imposed by the analytical model on the joint process of inflation and money growth. Econometric estimates indicate that the successful stabilization program implemented in Israel in July 1985 was more credible to the agents than either the earlier Israeli attempt in November 1984 or the Argentine programs.

[17] An example of this situation was the introduction of a currency board system in Argentina in 1991. In this case one price, namely the price of the US dollar, was fixed by law to be one unit of the local currency.

The government's signaling might substantially simplify the inference problem and increase the speed of learning on the part of the agents. However, up the extent that agents forecast impending changes in policy (in this case the introduction of price controls), signaling might also increase the short-term volatility of inflation and money growth. Finally, as documented in Section 5, in the absence of transaction costs, the welfare gains from a temporary increase in real balances might be high enough to induce agents to raise their real balances in the short-term following an inflation stabilization, even if they are not certain about the true nature of government policy and the eventual outcome of the stabilization attempt.

Table 1. Estimates of State-Dependent Components

Parameter	Argentina	Israel
β_1	3.455 (0.552)	1.186 (0.167)
β_2	2.395 (0.902)	0.851 (0.454)
β_3	9.272 (1.353)	8.627 (0.907)
β_4	16.481 (2.212)	18.722 (3.324)
σ_1	1.563 (0.151)	0.940 (0.104)
σ_2	3.089 (0.668)	0.940 (0.104)
σ_3	4.474 (0.459)	4.903 (0.560)
σ_4	2.471 (1.177)	4.903 (0.560)

Notes: For Israel, the constraints $\sigma_1 = \sigma_2$ and $\sigma_3 = \sigma_4$ were imposed. Bracketed figures denote estimated standard errors.

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Fig 1. Inflation Rate in Argentina

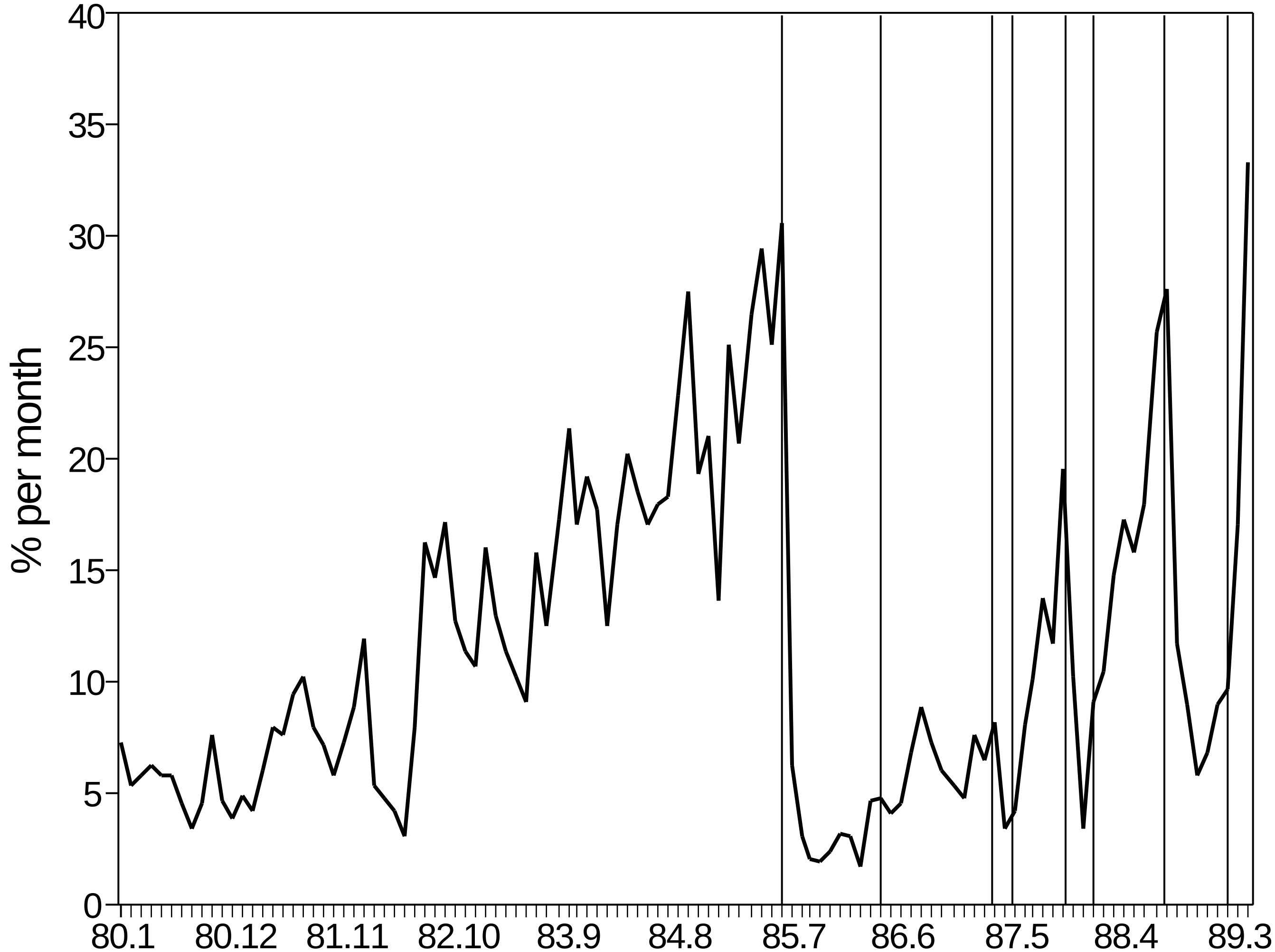

Fig 2. Inflation Rate in Israel

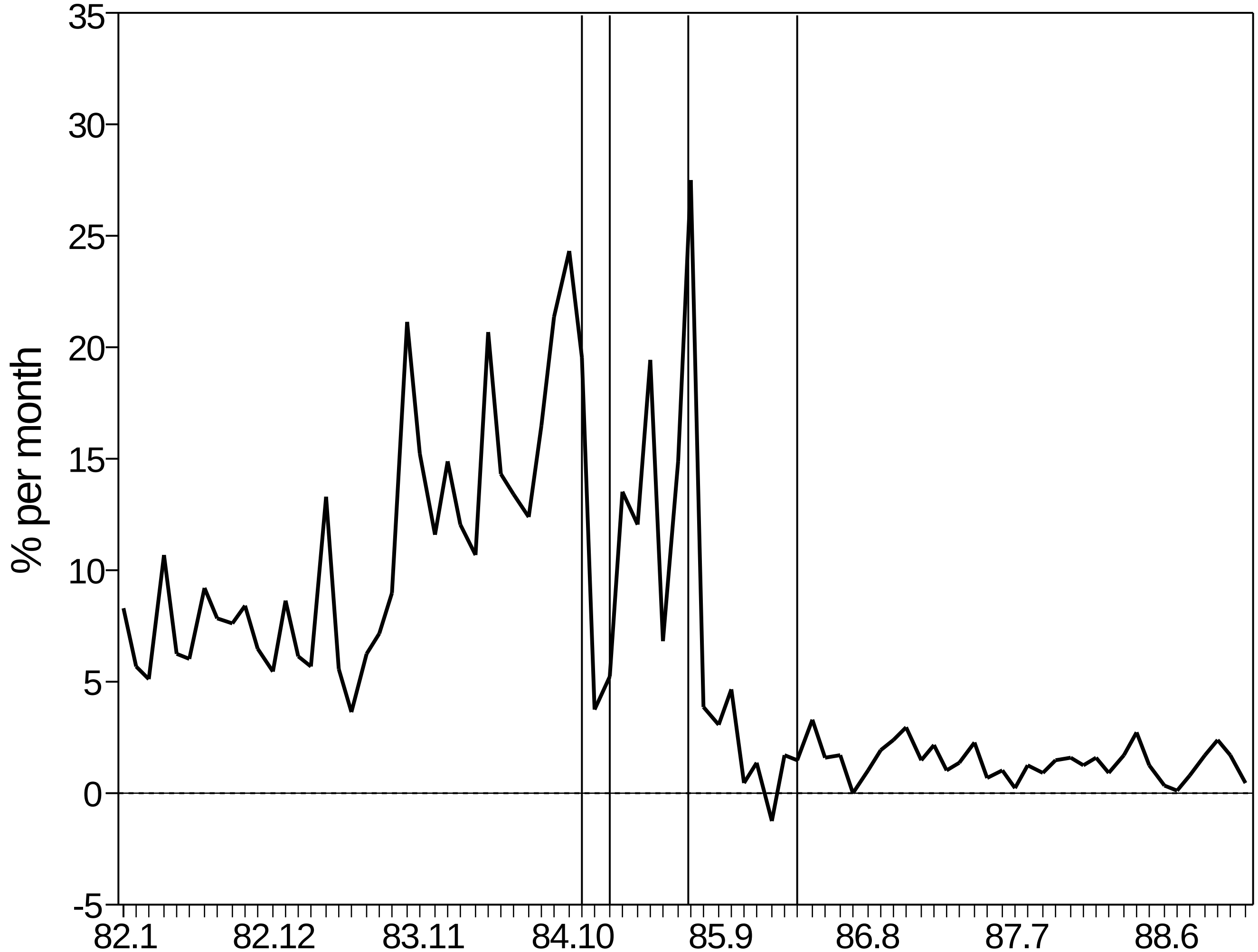

Fig 3. Path of Inflation after Change in Regime. Argentina

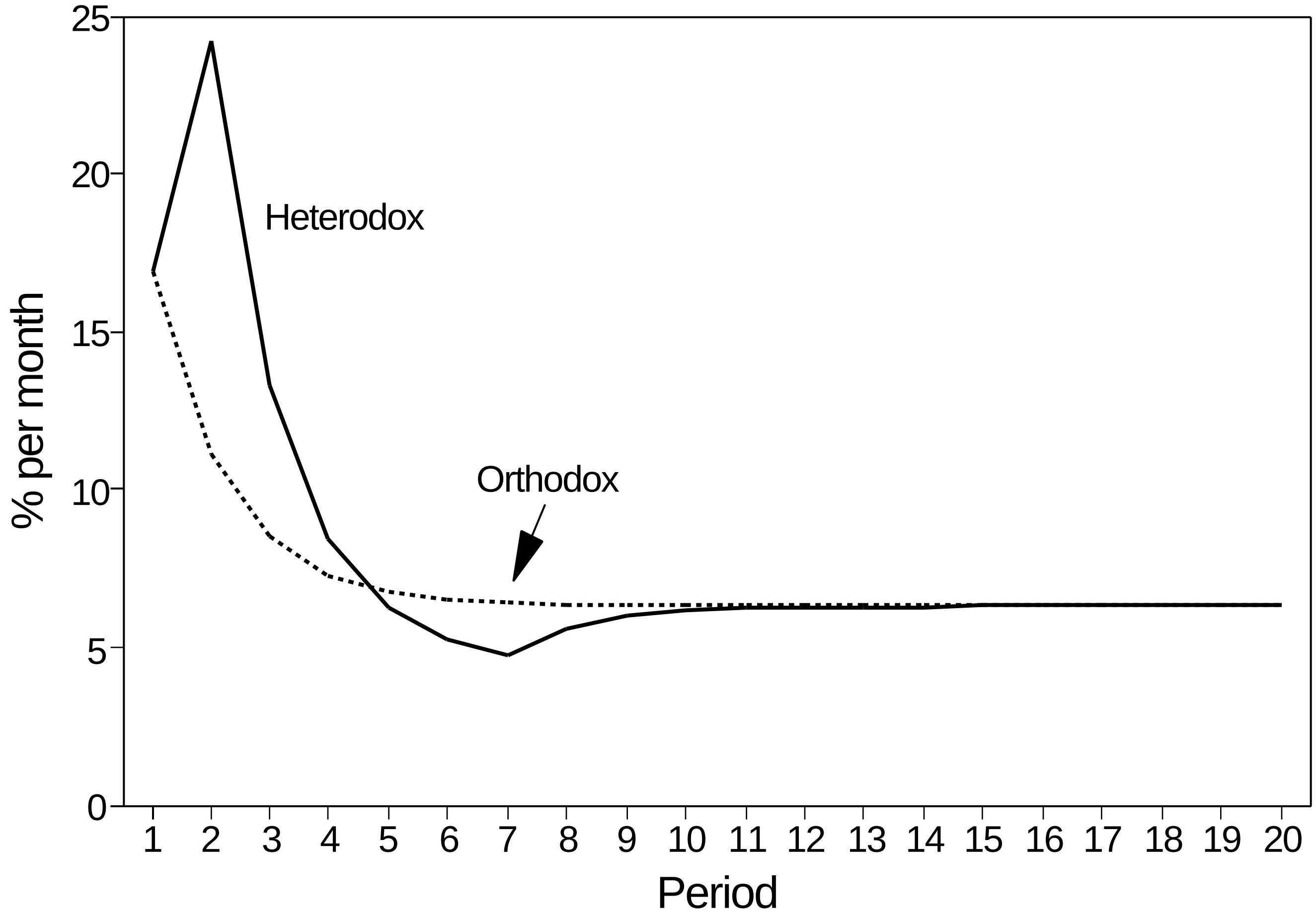

Fig 4. Path of Inflation after Change in Regime. Israel

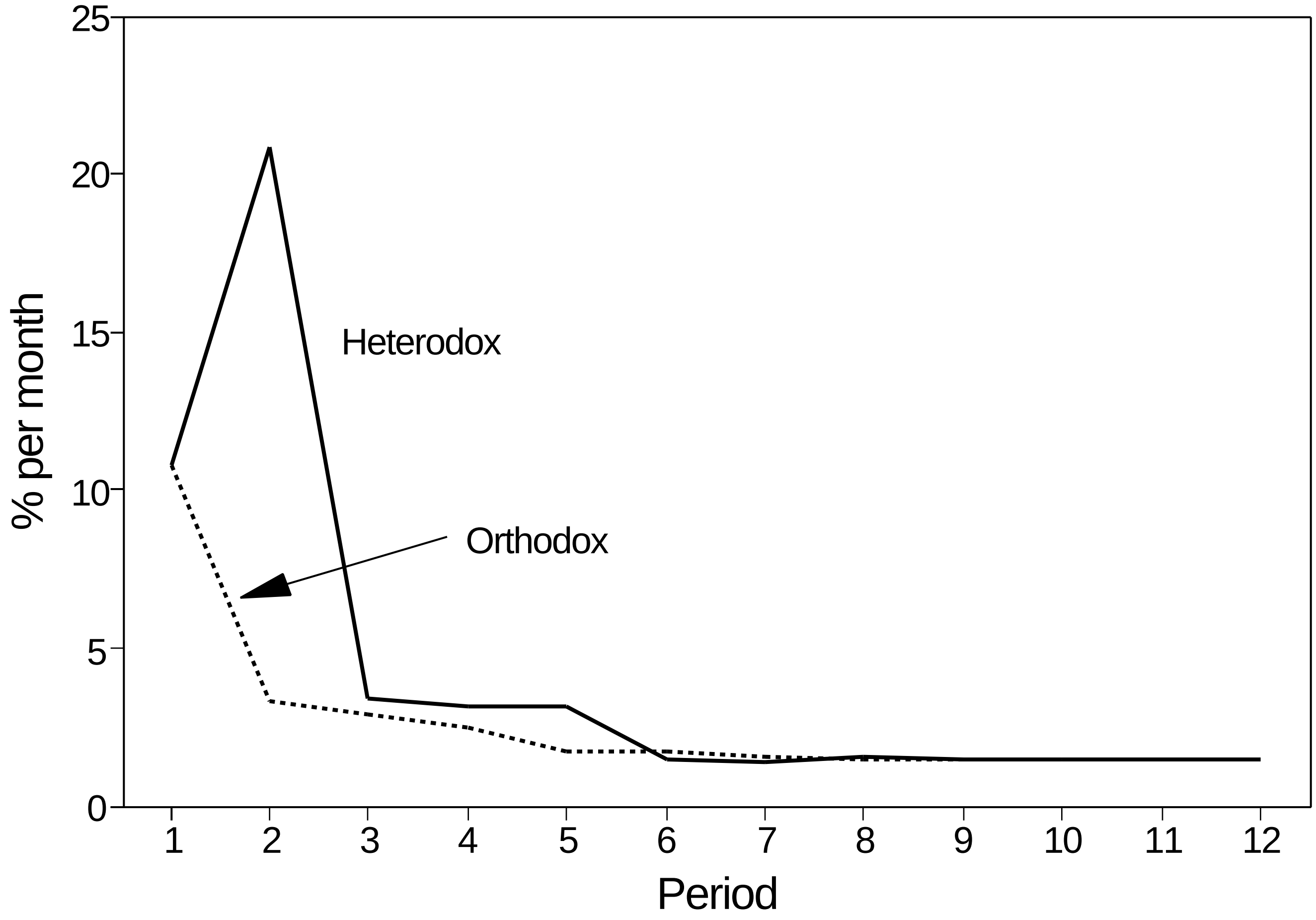

Fig 5. Change-in-Regime Component
Argentina

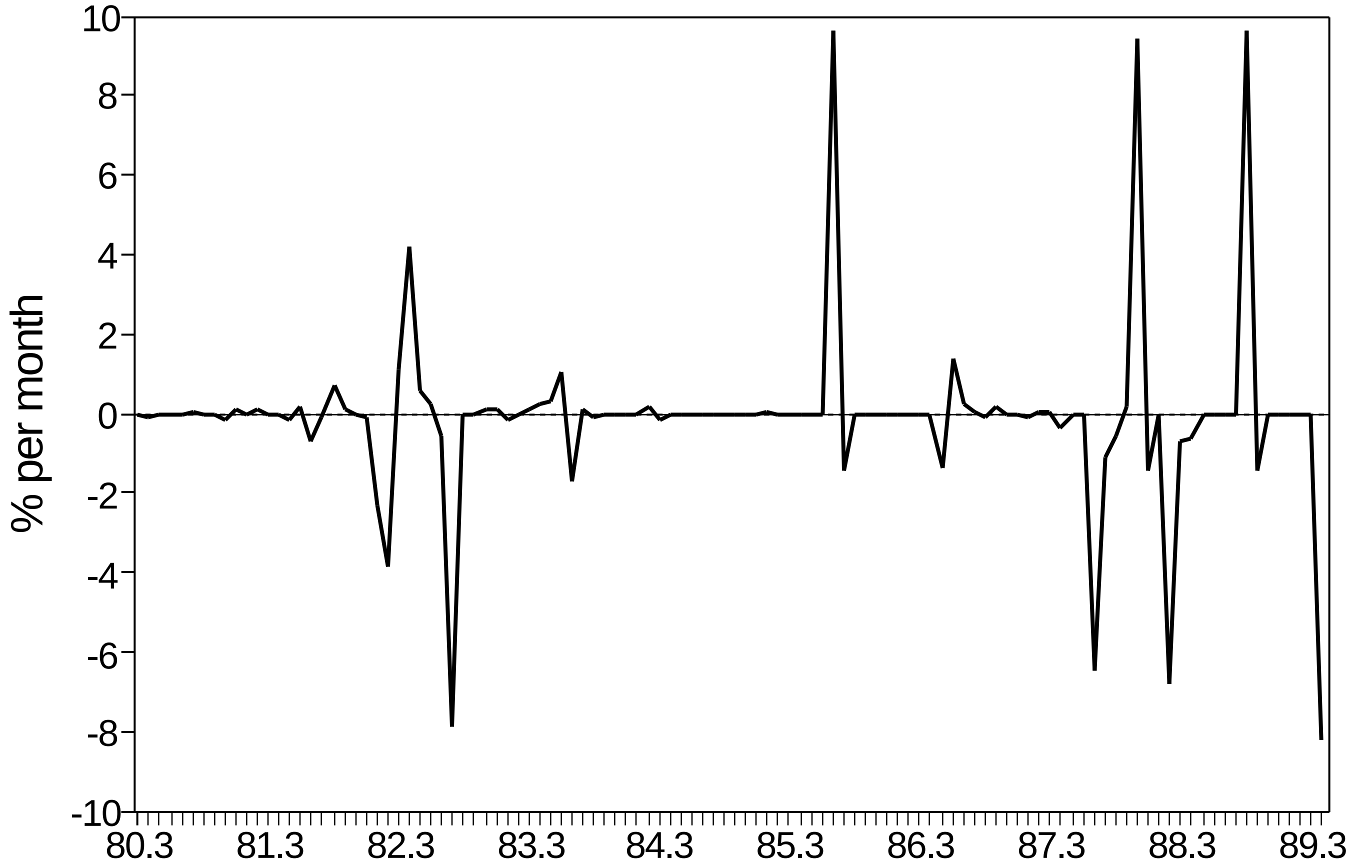

Fig 6. Change-in-Regime Component
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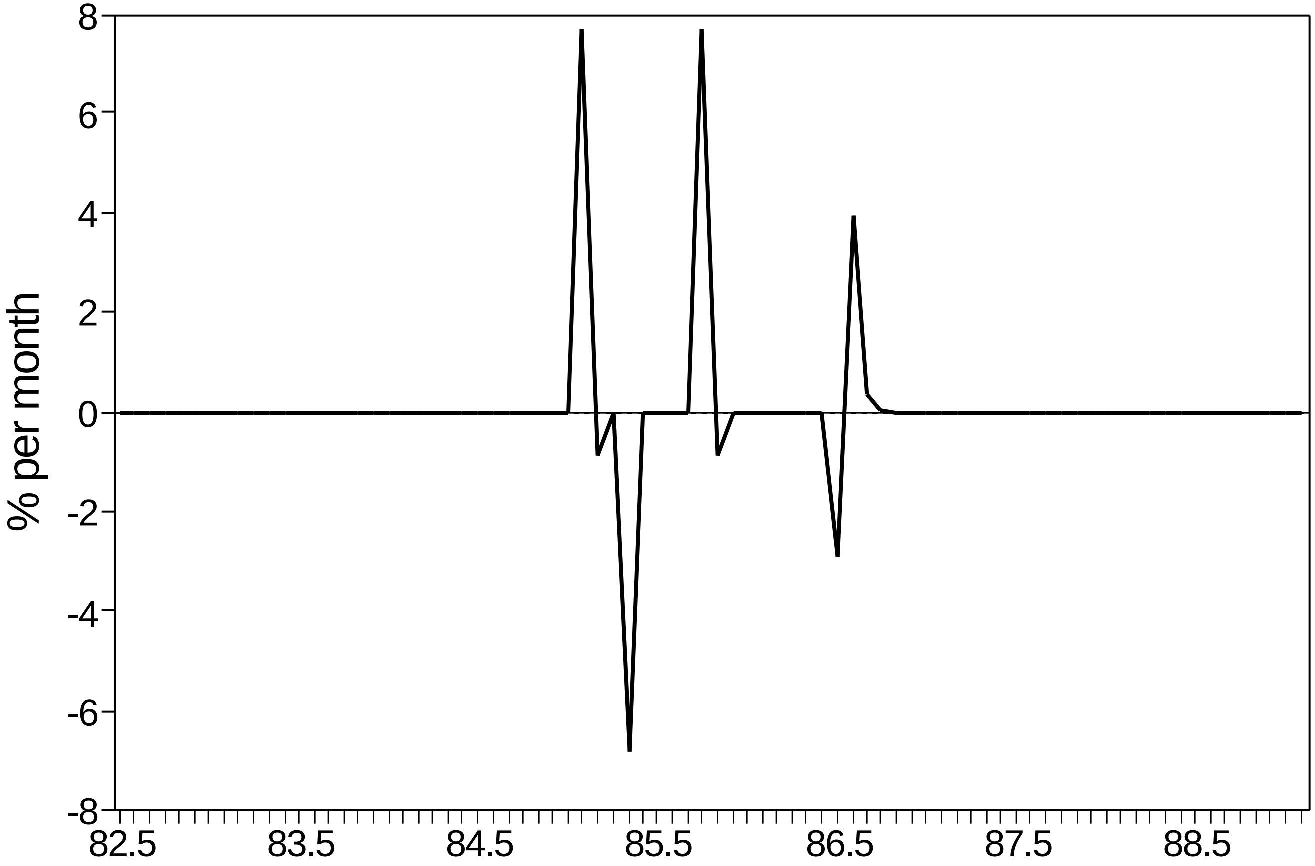

Figure 7. Agents' Inferred Probabilities. Argentina

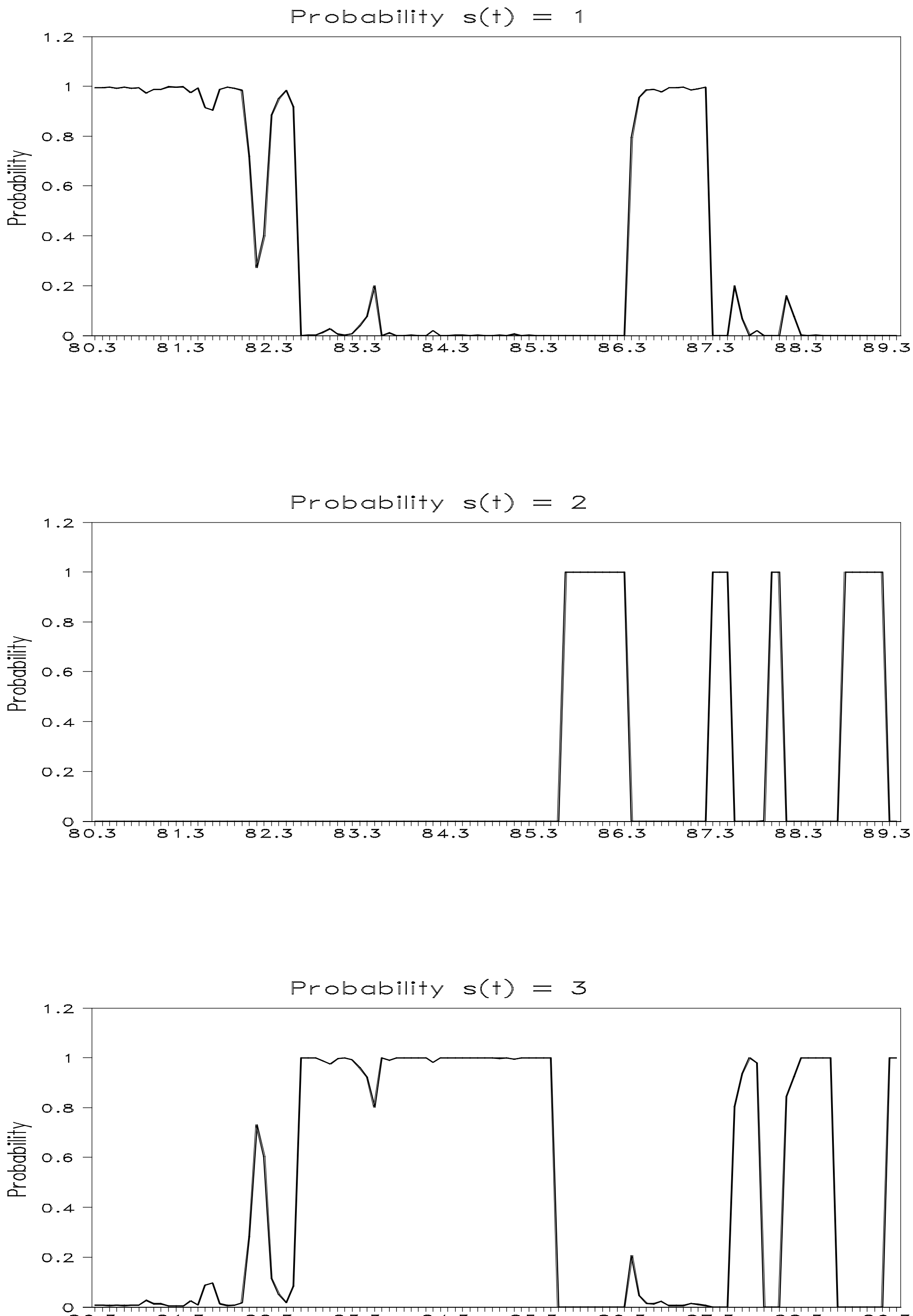

Figure 8. Agents' Inferred Probabilities. Israel

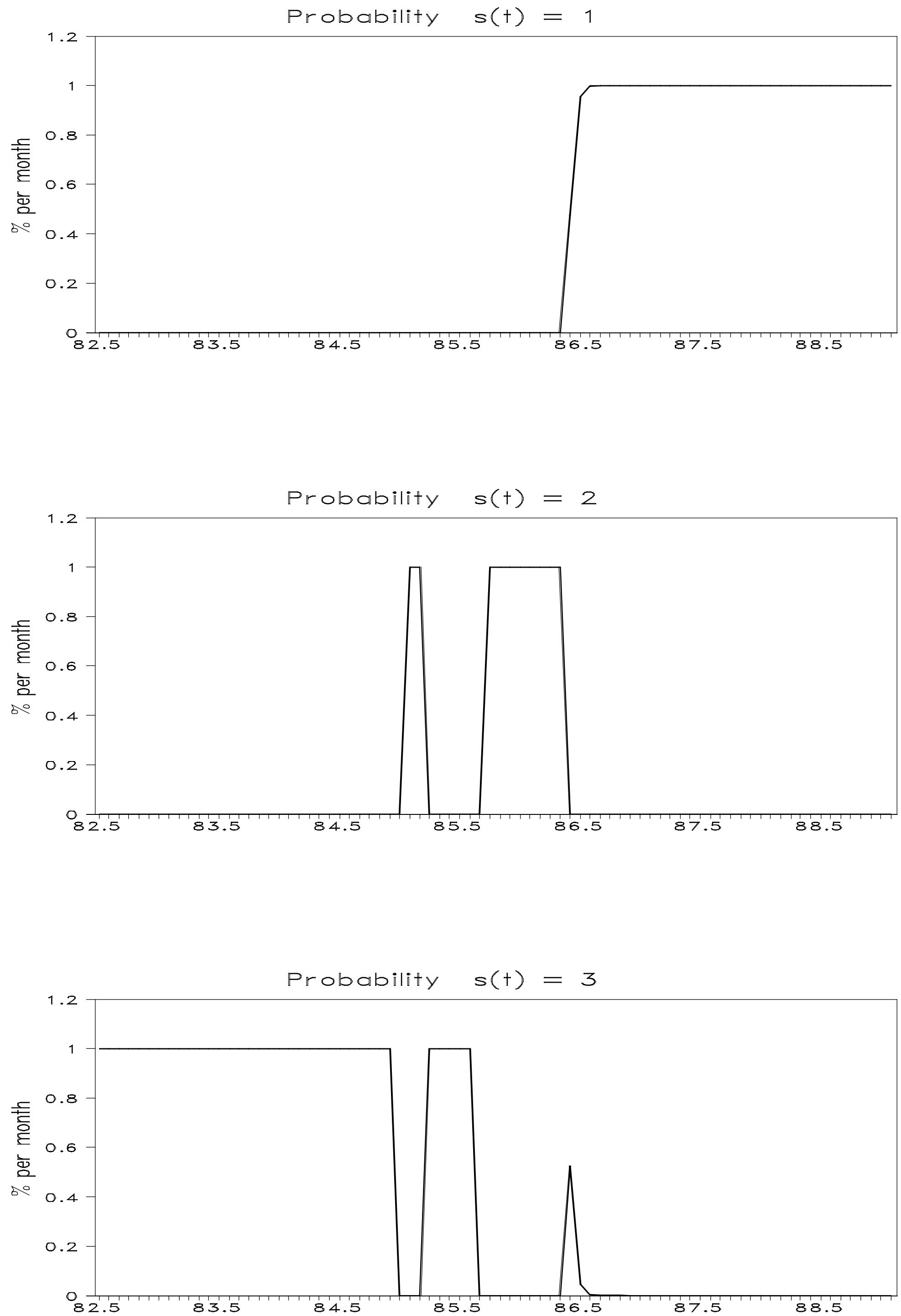

Figure 9. Effect of Credibility and Learning on Γ_t

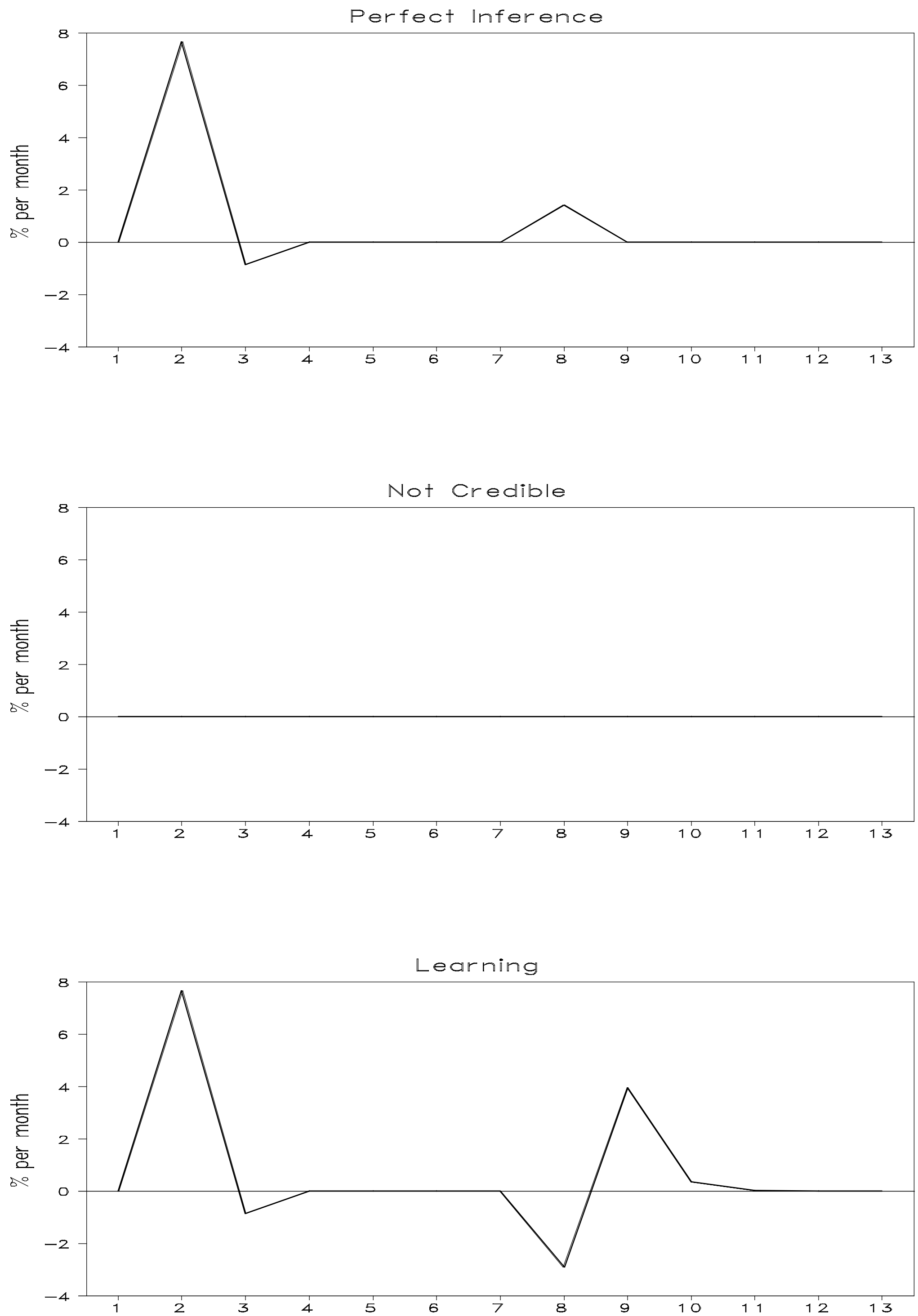

Figure 10. Effect of Probability of Success on Γ_t

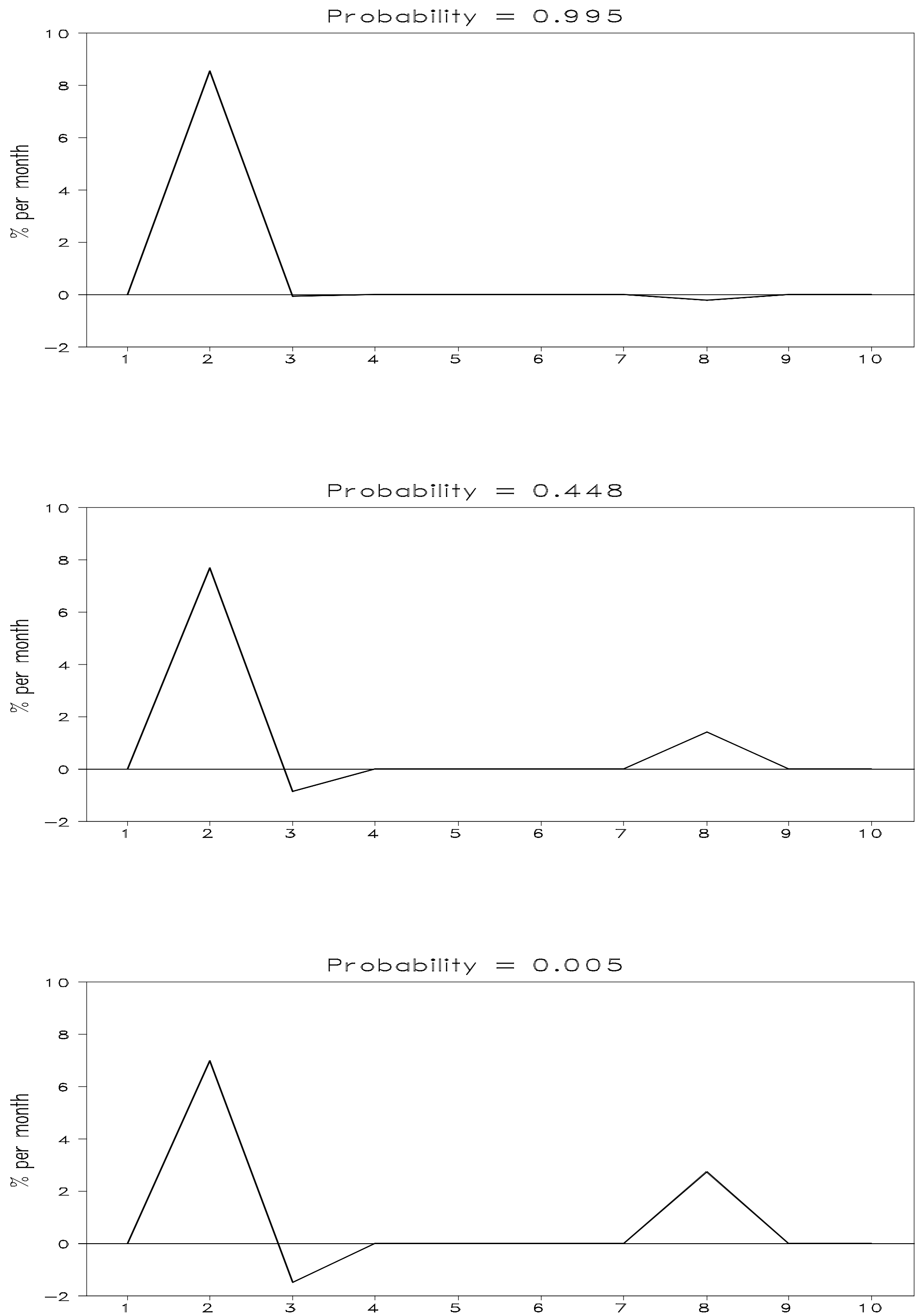

Figure 11. Effect of Permanent and Transitory Signaling on Γ_t