Nominal Shocks and Relative Price Variability:

An Empirical Study for the Peruvian Economy

by

Rossana C. Polastri

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David Orden (Chair)

Anya McGuirk

Daniel Nuxoll

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Relative Price Variability and Real and Nominal Shocks:

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Rossana C. Polastri

David Orden, Chair

Agricultural Economics

(ABSTRACT)

Inflation has been a recurrent and critical problem in many Latin American countries. Inflation is often combined with, among other problems, serious distortions in the structure of relative prices thus reducing efficiency of the pricing mechanism in allocating resources.

The purpose of this study is to examine the effects of inflation and other variables on relative price variability in Peru using two different types of models. After preliminary evaluation of the stationarity properties of the series, a relative price variability measure is constructed using monthly data on 32 components of the CPI over the period 1979:12-1988:07. For the first models, series of expected and unexpected inflation in Peru, real exchange rate movements, and U.S. relative price variability are constructed and the effects of these variables on observed relative price variability are determined. The results indicate that increasing levels and unpredictability of inflation cause increased dispersion of relative prices.

A distinction between expected and unexpected relative price changes is made in the second model. This distinction is relevant because not all price movements are viewed by agents as surprises that confuse price signals. To account for this distinction, a measure of conditional relative price variability is estimated using Engle's (1982) autoregressive conditional heteroskedasticity approach. Similarly, the conditional variance of domestic inflation is estimated and used as a measure of price uncertainty.

Effects of the time-dependent conditional variances of domestic inflation and real exchange rate on a weighted average of the relative price shocks normalized by their conditional variances are evaluated and found statistically significant. Finally, both methods of testing empirically the hypothesis that inflation uncertainty increases relative price variability provided consistent results.

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To Cristina

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CHAPTER I

INTRODUCTION

1.1 Introduction

Inflation has been a recurrent and critical problem in several Latin American economies. It is not surprising then to find its causes and consequences and alternative approaches to control it at the center of both stabilization and growth strategy debates in the region. The Latin American literature on inflation is extensive, starting with the structuralist school's conceptualization of the inflationary process and its debate with monetarism throughout the 1950s and 1960s.

While, high rates of inflation have been a characteristic of a few Latin American countries since the early post-war years, the decade of the 1980s witnessed a dramatic acceleration of inflation in a large number of countries in the region. Indeed, in recent years many countries, including Argentina, Bolivia, Brasil, Nicaragua and Peru, registered rates of inflation which surpassed rates typically considered hyperinflationary.

With inflation back in the forefront of the stabilization policy debate, Argentina, Brazil and Peru launched unorthodox stabilization programs in the mid 1980s, based on exchange rate and price controls, and Bolivia undertook a successful orthodox attempt at eliminating hyperinflation, relying on the stability of the exchange rate.

In this context, analyzing the costs and consequences of a very high and variable inflationary process becomes an issue of importance. Usually, inflationary situations are combined with, among other problems, serious distortions in the structure of relative prices. The welfare implications of excessive variability stem from the speed with which information on relative prices become obsolete, thus implying greater search risk than would be warranted under stable conditions. In this way, excessive price variability reduces efficiency of the price mechanism in allocating resources.

1.2 Problem Statement

The behaviour of inflationary expectations have been recognized as a prime determinant of the real effects of inflation. Recent theoretical developments and evidence brought by several empirical studies have suggested that the distribution of relative price changes is not independent of the distribution of inflation, in direct contradiction to the neutrality of money paradigm. This reopens the old question regarding money and inflation and their interactions with real phenomena. Cukierman (1984) illustrates this point clearly:

"A basic postulate of neoclassical economics is that relative prices are determined only by real factors, whereas the general price level depends on the quantity of money. A doubling of the quantity of money will, in this view, double all prices without affecting relative prices. This dichotomy between the determinants of relative prices and those of the general price level is a useful device to organize our thinking about economy. It should be viewed as a first approximation, however, rather than a full account of the possible relationship between relative prices and the general price level." p(84)

A number of hypothesis have been raised to explain the observed positive association between relative prices and some aspect of inflation. These theories usually emphasize the role of different characteristics of inflation in explaining this positive correlation. The approach based on rational expectations with imperfect information emphasizes the role of unexpected inflation and inflation variability in generating relative price variability in a multimarket model with imperfect information (Cukierman(1979) and Hercowitz(1981)).

An alternative approach builds on the presumption that nominal price changes are costly; that is, they are subject to menu costs. Within this approach the distribution of inflation and, in contrast with the imperfect information model, expected inflation affect the dispersion of prices.

Empirical work on the relationship between inflation and relative prices has also been extensive. Although the empirical studies differ in the econometric techniques employed, in the measure of variance of relative prices and in the type of the exogenous variables included, they have all reported some evidence supporting a positive correlation between relative price variability and inflation.

It is important to point out that most of the empirical studies have dealt with low-inflation and relatively stable economies. Isolating monetary from real effects on relative price changes for these economies may pose different challenges than in less stable economies, where the magnitude of the distortionary effects may be larger but also less tractable. Only a few studies of inflation and relative price variability have been undertaken in a high inflation context. For example, Blejer and Leiderman (1981) and Blejer (1983), have evaluated the relationship between inflation and relative prices for Mexico and Argentina, respectively. Analyzing in detail the characteristics and costs of relative price behaviour in Peru within the context of very rapid and variable inflation will be a useful contribution to this part of the literature. The results will convey important implications in the inflation-stabilization debate in these economies.

1.3 Objectives

The primary purpose of this thesis was to test empirically the relationship between relative price variability and inflation in a context of high and volatile inflationary economy. The empirical analysis focused on two hypothesis. The first one followed the traditional method of testing this hypothesis:

Hypothesis 1. The relative price variance is a function of inflation uncertainty.

The multimarket model with imperfect information has the theoretical implication that the variance of relative price forecast errors on local output is positively related to the variance of aggregate nominal and real shocks. However, most of the empirical work have used observed relative price variability as the dependent variable and regress it on variables representing nominal shocks such as unexpected inflation. The use "observed relative price variability" has the restrictive assumption that all changes in relative prices are reflecting changes in relative supplies and demands. It does not allow to distinguish between expected and unexpected relative price changes.

Conditional relative price variability is defined as the average variance of relative price forecast errors across markets. Since this measure is a more appropriate index because it is reflecting directly the forecasting uncertainty of relative prices and supply conditions, the second hypothesis tested was:

Hypothesis 2. The conditional variance of relative prices is a positive function of conditional variances of nominal and real shocks.

1.4 Procedures

The models estimated to test the first hypothesis had the general functional form:

$$RPV_t = f(DP_t^u, DP_t^e, RER_t, RPV_t^{US})$$

where RPV_t is observed relative price variability, DP_t^u is unexpected inflation and is used as a proxy of inflation uncertainty. DP_t^e is expected inflation, RER_t is the real exchange rate and RPV_t^{US} is U.S. relative price variability.

The measure of observed relative price variability was constructed based on a 32 commodity disaggregation of the monthly Peruvian CPI. Let the rate of change in the *ith* price between periods *t-1* and *t* be $Dp_{i,t}$ and defined as the difference in the natural logarithm of the *ith* price in the two periods:

$$Dp_{i,t} = \ln(p_{i,t}) - \ln(p_{i,t-1}) \tag{1.1}$$

An aggregate price level for the set of *n* commodities is P_t. Then the rate of change of this index is defined as the weighted average of the rate of change for individual commodities:

$$DP_t = \sum_{i=1}^{n} w_i (Dp_{i,t}) \tag{1.2}$$

where w_i is the average expenditure share on the *ith* commodity.

The measure most commonly used to quantify the degree of relative price variance is given by the weighted sum of squared deviations around the mean. This variance measure is as follows:

$$\begin{aligned} RPV_t &= \sum_{i=1}^{n} w_i[(\ln(p_{i,t}) - \ln(P_t)) - (\ln(p_{i,t-1}) - \ln(P_{t-1}))]^2 \\ &= \sum_{i=1}^{n} w_i(Dp_{i,t} - DP_t)^2 \end{aligned} \tag{1.3}$$

With respect to the explanatory variables, expected and unexpected inflation were constructed using an autoregressive inflation model consisted of lagged values of observed inflation. In addition to inflation uncertainty, real and nominal foreign shocks may also be causing relative price variability. In a country like Peru, which has an important external sector, it is plausible that domestic price variability is affected by the behaviour of foreign prices and other external-sector variables. Foreign relative price variability would affect domestic relative price variability, even when trade composition remains unchanged. In addition, if foreign relative prices display more stability than domestic variables, it follows that relative price variability should decline as additional commodities become exposed to international rather than domestic pricing.

The empirical measure of the real exchange rate was constructed by dividing the relevant exchange rate (Intis by U.S. dollars) by Peru's consumer price index and multiplying it by U.S. consumer price index.

U.S. relative price variability was constructed using the index formula from equation 1.3, based on dissagregation to 8 commodity groups.

The second procedure to explore the relationship between relative price variability and inflation uncertainty utilized different measures of these variables. This hypothesis that conditional relative price variability depends on the conditional variance of real and nominal shocks was tested by estimating the following model:

$$CRPV_t = f(\sigma^2_{P,t},\ \sigma^2_{X,t},\ \sigma^2_{US,t})$$

where $CRPV_t$ is the conditional relative price variance and ${\sigma_P}^2$ is the conditional variance of domestic inflation. Two other shocks are also included, a real exchange rate shock with variance ${\sigma_X}^2$ and a foreign nominal shock with variance ${\sigma_{US}}^2$.

Using Engle's (1982) autoregressive conditional heteroskedasticity (ARCH) approach, a time-varying conditional variances of individual relative prices of 8 disaggregated commodity groups, the aggregate domestic price level, real exchange rate and the U.S. price level were modelled and estimated. To determine if these series were better represented by an ARCH model a Lagrange multiplier test was conducted. Then, conditional variances were estimated and used for finding the determinants of conditional relative price variance.

The conditional relative price variance is measured as average variance of the relative price forecast errors across markets. Let $\epsilon_{i,t}$ be the relative price forecast error:

$$\epsilon_{i,t} = [\ln(p_{i,t}) - \ln(P_t)] - E_{t-1}[\ln(p_{i,t}) - \ln(P_t)] \quad (1.4)$$

then, the conditional relative price variance is measured as:

$$CRPV_t = \sum_{i=1}^{n} w_i E_{t-1}(\epsilon_{i,t})^2 \quad (1.5)$$

The relative price in the previous period, $\ln(p_{i,t-1}) - \ln(P_{t-1})$, has been replaced by the agents expectations at the previous period of the relative price level, $E_{t-1}[\ln(p_{i,t}) - \ln(P_t)]$. This second index of relative price variance reflects directly the forecasting uncertainty of relative prices and supply conditions on individual markets, which is the main concern of this thesis.

1.5 Synopsis of Results

Empirical results for both models suggest the impact of monetary shocks on relative prices. For the first model, it was found that unexpected inflation and the real exchange had a significant effect on observed relative price variability, whereas expected inflation and U.S. relative price variability were not significant. Results for the second model confirm that price uncertainty, measured as the conditional variance of inflation, had a significant effect on conditional relative price variability.

While the conditional variance of U.S. had no effect on domestic relative price variance, consistent with what was found in the first model, the estimated parameter of the conditional variance of the real exchange rate was also found significant.

1.6 Organization of the Thesis

The organization of the thesis is as follows: a literature review focused on theoretical and empirical studies is presented on Chapter II. Chapter III contains a brief summary of the Peruvian macroeconomic background for the period 1976-1990. The description on Chapter II provides basis for specifying the models of relative price variability and inflation uncertainty and to interpret the empirical results. Chapter IV includes the empirical analysis, where the methodology employed and results are discussed. Finally, Chapter V summarizes the results and offers conclusions.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The coexistence of high inflation and low real growth has received considerably attention during the last decades. Analytic contributions in the imperfect information market-clearing framework have shown how uncertainty about inflation can reduce the efficiency of the price system and how relative price change variability is likely to be greater when there are unanticipated changes in the price level. The existence of a positive correlation between inflation and the dispersion of relative prices have been tested by a number of studies.

Chapter II focuses on the studies that have investigated the relation between inflation and relative price change variability. Section 2.1 presents a review of the theoretical approaches that have studied this relationship. A summary of empirical studies that have tested statistically the relation between inflation and relative price change variability is included in Section 2.2.

2.2 Theoretical Literature

The study of the relationship between the variance of relative price changes and inflation has been approached by a multimarket model that uses a set of assumptions about the determinants of demand and supply in each market as well as the amount of information that producers and consumers have about other prices in the economy. Typically, in these models the variability of relative price changes depends on some function of the inflation rate, such as the unexpected inflation.

The first type of model, known as the Equilibrium Misperceptions Model is characterized by price flexibility and by agents lacking information about the price level and about the source of disturbances. This approach hypothesizes that shocks cause both inflation and relative price variability and that the latter only occurs through misperception of inflation.

In the second type of model, the assumption of price flexibility is relaxed by postulating that prices are more likely to increase than to decrease. However, producers and consumers are assumed to posses complete information about the price level and the source of disturbances. This latter type is known as the Asymmetric Price Response Model.

2.2.1 Equilibrium Misperceptions Models

The most salient features of this kind of models are as follows: it is a multimarket model where agents lacks information about the price level, and therefore their relative price, and also about the future course of monetary policy. Second, the price in each market will adjust so as to maintain market equilibrium at every single moment of time. Because agents lack of information about the general price level, they must make decisions based on what they perceive their price relative to be, which in turn is based on their perceptions of both the general price level and the future course of monetary policy. So long as the perceived and the actual prices are equal, producers and consumers will not alter their selling and buying plans. However, agents may misperceive their relative prices since the course of events may differ from what they were expected to be. It is only such misperceptions which can lead to changes in purchases and selling plans in this model.

Within this framework, there are two types of models. The first type of model is deterministic in nature and the process whereby agents form expectations is not explicitly modeled. Parks (1978) and Blejer and Leiderman (1979) develop models that belong to this type. The second type of model is stochastic in nature and expectations are modeled as rational (Lucas 1973; Barro 1976; Hercowitz 1981; Cukierman 1984).

2.2.1.A. Partial Information Multimarket Model

This model was developed by **Parks (1978)**, who presents an interpretation of the variability of relative price changes in terms of a multimarket framework that is more restrictive than the second type of model. Parks restricts inflationary expectations and therefore the amount of unanticipated inflation to be identical across all markets. In contrast, Lucas' (1973) model permits suppliers in a given sector to use current price information from their own but no others markets in developing a price predictor.

Demand and supply for each market are expressed by the following equations:

$$q^s_{it}=\alpha_i+\beta(p_{it}-E(P_t))+\gamma_i T \tag{2.1}$$

$$q^d_{it}=\eta_{ii}p_{it}+\eta_{io}M_t+\theta_i \tag{2.2}$$

where

q_{it} = logarithm of the quantity of the ith commodity at time t,

p_{it} = logarithm of the price of the ith commodity at time t,

$E(P_t)$ = logarithm of the anticipated price level at time t,

M_t = logarithm of nominal money holdings at time t,

T = time.

The coefficient γ is the trend rate of growth of output, β_i is the supply elasticity with respect to changes in real price of good i, η_{ii} is the own-price elasticity, and η_{io} is the income elasticity, of demand.

No random elements are present and homogeneity of degree zero in prices and income implies $\eta_{ii} = -\eta_{io}$. The assumption that markets clear, given supplier's expectations about the general rate of inflation, results in a reduced form:

$$p_{it} = \frac{-n_{ii}M_t + \beta_i E(P_t) + \theta_i - \gamma_i t}{\beta_i - \eta_{ii}} \tag{2.3}$$

Taking first differences to equation (2.3) and subtracting inflation rate (DP_t) from both sides, Parks arrives at the following equation:

$$Dp_{it} - DP_t = \frac{1}{\beta_i - \eta_{ii}}\left[-\eta_{ii}(DM_t - DP_t) - \beta_i(DP_t - E(DP_t) - \gamma_i\right] \tag{2.4}$$

The equation for relative price change variability is obtained by substituting equation (2.4) into the expression for RVP_t:

$$\begin{aligned} RVP_t &= \sum_{i=1}^{n} \omega_{it}(Dp_{it} - DP_t)^2 \\ &= \sum_{i=1}^{n} \frac{1}{\beta_i - \eta_{ii}}[-\eta_{ii}(DM_t - DP_t) - \beta_i(DP_t - E(P_t)) - \gamma_i]^2 \end{aligned} \tag{2.5}$$

From equation (2.5) in can be seen that in this model the variability of relative price changes is only a function of changes in real money and of unexpected inflation. After expanding this expression it will be noted that both linear and quadratic terms of real money changes and unexpected inflation will be determinant variables. Since Parks model is nonstochastic in nature, it does not easily yield a relation between general and relative price variability.

2.2.1.B. Partial Information with Rational Expectations Model

The second type of models are referred as the rational expectation models of relative prices. In these models, demand and supply are affected by random shocks, in contrast to those just considered. This sub-section will concentrate on **Hercowitz's (1981)** model proposed in his study of the German hyperinflation. Hercowitz's model is based on earlier work by Barro (1976) that used the localized markets framework described by Lucas (1973) to link the dispersion of relative prices to the variance of money growth. There are two key elements in Hercowitz's model, first, individuals possess incomplete current information and, second, demand and supply in each market reacts to relative prices as they are locally perceived. Individuals in the economy do not have full current information about the general price level since they operate in markets in which information does not flow instantaneously. However, individuals have information about the current price of the good that is traded in the market in which they currently operate. Demand for good *i* assumes the log-linear form:

$$q_{it}^{d} = -\alpha_{i}^{d}(p_{it} - E(P_{t})) + (M_{t} - E(P_{t})) + \varepsilon_{it}^{d} \tag{2.6}$$

and supply for good *i* is given by:

$$q_{it}^{s} = \alpha_{i}^{s}(p_{it} - E(P_{t})) + \varepsilon_{it}^{s} \tag{2.7}$$

where all the variables are defined as above except the following:

ϵ^{s}_{it} = supply random shock in ith market at time t

ϵ^{d}_{it} = demand random shock in ith market at time t

For each free good, $[p_{it} - E_i(P_t)]$ is the locally perceived relative price and $-\alpha^{d}_{i}$ is the (negative) elasticity of demand with respect to this relative price, which varies across markets. Demand is also influenced by the term $[M_t - E_i(P_t)]$ which reflects a real balance effect. The positive elasticity of supply with respect to the locally perceived price is α^s_i and is allowed to differ among markets.

Market clearing implies the equilibrium price:

$$p_{it} = \left[1 - \frac{1}{(\alpha^s_i - \alpha^d_i)}\right] E(P_t) + \frac{1}{(\alpha^s_i + \alpha^d_i)} \left[M_t + (\varepsilon^d_{it} - \varepsilon^s_{it})\right] \qquad (2.8)$$

In order to obtain a link between equilibrium prices p_{it} and VP_t, an analytical expression for $E(P_t)$ is needed. Hercowitz expresses P_t as a function, with unknown parameters, of a specified set of exogenous variables:

$$P_t = \Pi_1 M_{t-1} + \Pi_2 g_t + \Pi_3 m^e_t \qquad (2.9)$$

where g_t is the expected money growth rate and m^e_t is unpredictable part of the money growth rate. The growth rate of the money stock ($m_t = M_t - M_{t-1}$) is defined as:

$$\begin{aligned} m_t &= \sum_{i=1}^{n} \beta_i X_{it} + m^e_t \\ &\equiv \quad g_t \quad + m^e_t \end{aligned} \qquad (2.10)$$

where the X_{it}'s are variables (past or current) that can be observed in all locations and the β's are known coefficients. The quantity m^e_t is a random variable with zero mean and variance σ^2_m.

To obtain the general price level, Hercowitz takes expectations to equation (2.9) and substitutes $E(P_t)$ back into the expression for equilibrium price of the ith commodity, and finally averages with respect to the densities of λ_i ($\lambda_i \equiv 1/[\alpha^s_i+\alpha^d_i]$) and ϵ_{ti} ($\epsilon_{it} \equiv \epsilon^d_{it} - \epsilon^s_{it}$):

$$P_t = M_{t-1} + g_t + \left[\frac{\sigma_m^2+\sigma_\epsilon^2}{\sigma_m^2+(1/\lambda)\,\sigma_\epsilon^2}\right] m_t^e \tag{2.11}$$

The expression for relative price of the ith commodity is:

$$p_{it} - P_t = (1-\theta)(\lambda_i-\lambda)m_t^e + [\theta + \lambda_i(1-\theta)]\,\epsilon_{it} \tag{2.12}$$

where

$$\lambda_i = (\alpha_i^s+\alpha^d)^{-1}$$

$$\lambda = E(\lambda_i)$$

$$\theta = \frac{\sigma_m^2}{\sigma_m^2 + (1/\lambda)\,\sigma_\epsilon^2}$$

Taking first differences of the relative price expression and substituting into the expression for variability of relative price changes, Hercowitz finds that the variability of price changes depends on agent's misperceptions between real shocks, σ^2_ϵ, and nominal shocks, $(m^e_t - m^e_{t-1})^2$:

$$RVP_t = 2(1-\theta)^2\sigma_\lambda^2\sigma_\epsilon^2 + 2[\theta - (1-\theta)^2\lambda]\,\sigma_\epsilon^2 + (1-\theta)2\sigma_\lambda^2(m_t^e - m_{t-1}^e)^2 \tag{2.14}$$

where $\sigma^2_\lambda = \text{Var}(\lambda_i)$.

Summarizing, Hercowitz modifies Barro's framework by interpreting each location to be the market of a specific commodity, characterized by a particular excess demand elasticity. Because elasticities vary across markets, aggregate shocks affect each commodity price differently. Therefore, in this modified setup relative price variability is positively related to the magnitude of these shocks (equation 2.14). The model also predicts that systematic or perceived money growth is neutral with respect to price dispersion. A money shock in this model is defined to be a component of money growth that is currently unobservable and cannot be inferred from currently available information.

2.2.1.C. Partial Information, Rational Expectations and Price Controls

Literature that explains relative price variability within a partial information multimarkets framework typically assumes that price in all markets are determined by market clearing. However, in many countries a certain number of prices is either directly set by the government or regulated by it. Adjustments in the prices of these goods are made at discrete intervals and are widely and instantaneously disseminated by the media. As a result individuals in all markets have up-to-date information on that component of the general price level which is set by the government. This means that the component of the general price level which is confused with relative price movements is smaller than the same component in an economy in which all prices are freely determined by the market.

Cukierman and Leiderman (1984) extended the imperfect-information model with rational expectations in order to incorporate this feature. The model is similar to the one proposed by Hercowitz (1981), with the difference that the economy consists of two sectors with different market mechanisms. There is a *composite controlled good*, whose price is determined by the government, and a goods sector whose prices are determined by market clearing as in multimarkets rational expectation models (Lucas 1973; Barro 1976; Cukierman and Wachtel 1979; Hercowitz 1982). Cukierman and Leiderman designates the term ***free goods*** to the goods that belong to the segment of the economy with market clearing prices.

Using Theil's (1967) variance decomposition, the variance of relative prices is attributed to terms involving the variance of relative prices within the group of *free goods*, the variance of relative prices within the group of goods whose prices are controlled, and the variance between the two groups. The last two variances are affected by governmental price setting policy in the controlled sector of the economy. Cukierman and Leiderman concentrate on the first component of the variance of relative prices.

A major result of this extended version is that in addition to aggregate unanticipated shocks, relative prices within the non controlled section of the economy is also affected by the extent to which the price of the controlled good is not synchronized with the nominal supply of money. This effect is perfectly anticipated and arises because of divergences in supply and demand elasticities among markets within the free sector of the economy.

Cukierman and Leiderman's equations for supply and demand are similar to the ones assumed in the previous framework, with the difference that the parameter of the real balance is not restricted:

$$q_{it}^{d} = -\alpha_i^{d}(p_{it} - E(P_t)) + \delta(M_t - E(P_t)) + \epsilon_{it}^{d} \tag{2.15}$$

$$q_{it}^{s} = \alpha_i^{s}(p_{it} - E(P_t)) + \epsilon_{it}^{s} \tag{2.16}$$

and the money growth equation has the same functional form as in Hercowitz's model (equation 2.10).

The general price level is a weighted average of all prices including in particular prices of *free goods* and of controlled goods. The logarithm of the general price level is:

$$P_t = \sum_{i=1}^{n} u_i p_{it} + u_c p_t^c \tag{2.17}$$

where u_i is the weight of the ith free good in the general index and u_c is the weight of the controlled good in the general index and $\Sigma_i u_i + u_c = 1$.

Equation 2.7 and 2.8 (from section 2.2.1.B), together with rational expectations, imply that individual prices in the *free goods* sector and the actual and perceived values of the general price level are determined simultaneously. Since the model is log-linear, they propose a solution of the form:

$$P_t = \Pi_1 M_{t-1} + \Pi_2 g_t + \Pi_3 m_t^e + \Pi_4 p_t^c \tag{2.18}$$

for the general price level, where $\Pi_i (i=1,...4)$ are unknown coefficients to be determined. Equation 2.9 and 2.18 differ only the last term ($\Pi_4 p^c{}_t$), which is included as an exogenous variable since this price is known by the economic agents with certainty. Then, the rational perception of P_t in the *ith* free market is:

$$E(P_t | I_{it}) = \Pi_1 M_{t-1} + \Pi_2 g_t + \Pi_3 E(m^e_t | I_t) + \Pi_4 p^c_t \tag{2.19}$$

where I_{it} is the information set available to individuals in market *i* at time *t*. This information set includes g_t, M_{t-1}, the current values of the individual price p_{it}, and the price $p^c{}_t$ of the controlled good.

Using the method of undetermined coefficients and the optimal forecast (in the mean square sense) of $m^e{}_t$ given I_{it}, Cukierman and Leiderman obtain the following solution for equilibrium price in free market *i*:

$$\begin{aligned} p_{it} = P_t &+ \frac{\delta \lambda_i u_c}{(\delta k \lambda_m + u_c)} (M_{t-1} + g_t - p^c_t) \\ &+ \frac{(1 - k\theta)\lambda_i + k\theta\lambda_m}{1 - k\theta + \delta k \theta \lambda_m} (\delta m_t + \epsilon_{it}) \end{aligned} \tag{2.20}$$

where $k \equiv \Sigma_i u_i < 1$ is the sum of the weights of the *free goods* and $\lambda_m \equiv (1/k)\Sigma_i u_i \lambda_i$ is the weighted mean value of λ within the group of *free goods*.

The measure of the variance of relative price changes in the free sector is given by:

$$VP^F_t \equiv E_\omega \sum_{i=1}^{n} \frac{u_i}{k} (Dp_{it} - DP^F_t)^2 \tag{2.21}$$

$$P^F_t \equiv \sum_{i=1}^{n} \frac{u_i}{k} p_{it} \tag{2.22}$$

$P^F{}_t$ is the log of the mean price level within the group of *free goods*. The w under the expected value sign in this equation indicates that the expected value is over the distribution of relative excess demand shocks.

Substituting (2.18) into (2.20) and subtracting the resulting expression from (2.18), relative price within the group of *free goods* becomes:

$$p_{it} - P_t^F = \frac{\alpha u_c \Lambda_i}{\alpha k \lambda_m + u_c} (M_{t-1} + g_t - p_t^c) + \left[\frac{\alpha(1 - k\theta)\Lambda_i}{1 - k\theta + \alpha k\theta\lambda_m} \right] m_t^e + \left[\frac{(1 - k\theta)\lambda_i + k\theta\lambda_m}{1 - k\theta + \alpha k\theta\lambda_m} \right] \epsilon_{it} \tag{2.23}$$

where $\Lambda_i \equiv \lambda_i - \lambda_m$ is the deviation of the value of λ in market i from its mean value within the group of *free goods*. Taking first differences to equation (2.21) and substituting into (2.19), the expression for the variance of relative price changes is

$$VP_t^F = C_0 + C_1(\epsilon_t - \epsilon_{t-1})^2 + C_2(g_t + \epsilon_{t-1} - Dp_t^c)^2 + C_3(g_t + \epsilon_{t-1} - Dp_t^c)(\epsilon_t - \epsilon_{t-1}) \tag{2.24}$$

where

$$C_0 \equiv \frac{[\lambda_m^2 + (1 - k\theta)V_\lambda]\sigma_\epsilon^2}{[1 - k\theta(1 - \delta\lambda_m)]^2} \tag{a}$$

$$C_1 \equiv \frac{\delta^2(1 - k\theta)^2 V_\lambda}{[1 - k\theta(1 - \delta\lambda_m)]^2} \tag{b}$$

$$C_2 \equiv [\frac{\delta u_c}{\delta k\lambda_m + u_c}]^2 V_\lambda \tag{c}$$

$$C_3 \equiv \frac{2\delta^2 u_c(1 - k\theta)V_\lambda}{(\delta k\lambda_m + u_c)(1 - k\theta(1 - \delta\lambda_m))} \tag{d}$$

$$V_\lambda \equiv \sum_{i=1}^{n} \frac{u_i}{k}(\lambda_i)^2 \tag{e}$$

$$\theta = \frac{\sigma_m^2}{\sigma_m^2 + \frac{1}{\lambda_m}\sigma_\epsilon^2} \qquad \text{(f)}$$

Equation (2.24) predicts first, that the variance of relative price changes depends positively through C_0 on the variance σ^2_w of relative excess demand shocks. Second, it depends on the level of current and past unanticipated nominal shock (ϵ_t and ϵ_{t-1}). Third, it is related to the divergence of the rate of change of the price of the controlled good from its neutralizing level ($\Delta p^{*c}_t \equiv \Delta[M_{t-1} + g_t]$), which turns out to be (g_t + ϵ_{t-1} - Δp^c_t). This implies that any increase in the absolute value of this divergence increases the dispersion of relative prices within the group of *free goods*. The last term of equation (2.24) is related to the interaction between the unanticipated nominal shock and the degree of nonneutrality induced by the choice of Dp^c_t.

It is important to notice the similarity of equation (2.24) the equation (2.14) obtained by Hercowitz. When there are no controlled prices in the economy, u_c=0 so that C_2=C_3=0, and equation (2.24) reduces to be similar to (2.14). Hercowitz allows σ^2_m to vary over time in the version of his model discussed here, whereas Cukierman and Leiderman are assuming it is constant. As will be seen in section 2.2.1, in a second study Hercowitz (1982) assumes that σ^2_m is constant over time and then equation (2.24) becomes identical to the one derived by Hercowitz, when the economy has no controlled-price sector.

2.2.2 Asymmetric Price Response Model

This type of model was introduced into the literature by Solow (1975). The two distinguishing features of this type of model are, first, that the agents have complete information about the general price level and about whether the disturbances are real or monetary. Second, price changes will be larger in absolute value for excess demand than if there is excess supply, i.e., prices are inflexible downwards.

Pauls (1981) formalizes this notion of asymmetric price response and derives its implications for the direction of causality between variability of relative price changes and inflation. In her analysis, consumers are assumed to be price takers, and their demand in each market is represented as

$$q_{it}^{d} = -\alpha_{it}^{d}(p_{it} - P_t) + \beta(M_t - P_t) + \epsilon_{it}^{d} \tag{2.25}$$

where all the variables are defined as above.

Producers are assumed to have some monopoly power that persists through time. Accordingly, they set prices so as to equate marginal revenue with marginal costs. Their supply response function is represented as

$$q_{it}^{s} = \alpha_{i}^{s}\left[1 + \frac{1}{\alpha_{i}^{d}}\right](p_{it} - Pt) + \epsilon_{it}^{s} \tag{2.26}$$

Notice that the model differs from the *equilibrium misperceptions models* in that producers and consumers know the general price level, P_t, and thus there is no need to compute its expected value, $E(P_t)$.

In order to obtain an expression for variability of relative price changes we need to know the excess demand in each market and how this, in turn, affects the price changes in that market. Excess demand in each market is:

$$q_{it}^{d} - q_{it}^{s} = -\frac{1}{\gamma_i(p_{it} - P_t)} + \beta(M_t - P_t) + \epsilon_t \tag{2.27}$$

where

$$\frac{1}{\gamma_i} = \alpha_i^d + \alpha_i^s \left[1 + \frac{1}{\alpha_i^d}\right] \tag{2.28}$$

$$\epsilon_t = (\epsilon_{it}^{d} - \epsilon_{it}^{s}) \tag{2.29}$$

The equation for price changes with the assumptions of this model is

$$p_{it} - p_{it-1} = f(q_{it-1}^{d} - q_{it-1}^{s}) \tag{2.30}$$

where the price change in the *ith* market in this period is a function of the excess demand during the previous period, which suggests that the price changes occur only to the extent that the excess demand is perceived to be permanent.

A possible expression for the function explaining price change is (Pauls 1981):

$$p_{it} - p_{it-1} = \beta(M_{t-1} - P_{t-1}) + \delta_i\eta(1,2)\epsilon_{t-1} \tag{2.31}$$

where

$\eta(1,2) = \eta_1$ if $\epsilon_{t-1} > 0$

$= \eta_2$ if $\epsilon_{t-1} < 0$, and

$$\eta_1 > \eta_2$$

The asymmetric price response of prices due to excess demand is captured by the assumption that $\eta_1 > \eta_2$.

After a number of transformations which are not presented here Pauls (1981), obtains the following expression for the variability of relative price changes:

$$RVP_t = R[\sum_{t=1}^{T} \frac{\epsilon_{t-1}}{N}]^2 \qquad (2.32)$$

where N and R are constants. Equation (2.30) implies that the variability of relative price changes depends only on the sum of real disturbances occurring in each of the markets. Pauls (1981) finds that an implication of the Asymmetric Price Response model is that the direction of the causality runs from RVP_t to inflation.

2.2.3 Summary and Conclusions

An association between the inflation rate and the variability of relative price changes is found in the Equilibrium Misperceptions Models, whether it is the deterministic version or the rational expectation approach. By contrast, the Asymmetric Price Response model suggests that price dispersion does not depend on the money growth rate, unexpected or expected, it depends on the sum of real disturbances in each market.

Cukierman and Leiderman's extension to the model developed by Hercowitz introduces an important aspect of the sources of relative price changes variability. Price controls are an important policy tool in many developing countries, whether they are used to maintain the cost of some basic basket below some level or in an attempt to change the path of inflation over time. Price controls are a permanent institution in many developing countries and not a temporary device for slowing inflation down, as during 1971-74 in the United States. In addition, they involve direct subsidization and price setting by the government. For these reasons, it is obvious these economies cannot be modeled assuming that all markets clear through free price adjustment.

An important aspect that is left underdeveloped in the theoretical models presented above is that they all abstract from open economy considerations. As will be seen in the next section, Blejer and Leiderman (1979) modified Parks' (1978) model separating the economy into traded and nontraded sectors.

2.3 Review of Empirical Studies

The relationship between inflation and other aggregates variables and the variance of relative prices has been tested empirically by a number of studies. Although the empirical studies differ in the econometric techniques used, in the measure of variance of relative prices, and in the exogenous variables considered, most of them have reported evidence supporting a positive correlation between the variability of relative price changes and inflation.

The nine articles reviewed here were chosen to provide a balanced view of the state of the literature on the association between inflation and relative price variability. The association has been studied both with and without a priori assumptions about the causality between the inflation rate and the variance of relative price changes. The authors who use no a priori assumptions about the direction of causality follow a purely statistical approach. Vining and Elwertowski's (1976) study falls in this category and they conclude that there is strong *statistical* evidence that the variance of individual prices and the degree of variability in the general price level move together.

Another group of authors impose a set of assumptions about the functioning of the markets, from which a relation between the variability of relative price changes and the inflation rate is derived. This relation is then tested statistically. Studying relative price variability at a cross-sectional (*intermarket*) level, Parks(1978) and Fischer(1981) conclude that both anticipated as well as unanticipated inflation increase relative-price variability.

Hercowitz (1981) finds that the hypothesis that variability of relative price changes depends on agent's misperceptions of real shocks and nominal shocks is supported when he uses German data for the hyperinflationary era. In Hercowitz's (1982) study, he finds support only for that the predicted effect of real shocks using U.S.A. data for the period 1948-76. Following Hercowitz' approach, Cukierman and Leiderman (1982) propose a modified partial information model, where a sector of controlled goods is included. They investigate the determinants of relative price variability for market-determined prices and find that the relative price variance within this segment of the economy is positively affected by both unanticipated monetary shocks and the divergence between the rate of price change price of the controlled good and the rate of money growth.

An important feature ignored in the preceding studies is that domestic price variability can be affected by the behavior or foreign prices. Blejer (1983) and Blejer and Leiderman (1982) find that anticipated inflation has no effect or only a weak effect on relative-price variability, whereas the unanticipated inflation appear to have a strong and significant effect. Finally, Neumann and Von Hagen (1991), using a different measure of relative price variability, find a positive relation between the conditional relative price variance and the variance of domestic monetary and foreign nominal and real shocks.

2.3.1 Single Economy Studies

Vining and Elwertowski(1976) show that the behaviour of the U.S. general price level is related in a statistically systematic manner to the behaviour of individual prices relative to each other, in the U.S. economy for 1948-1974. To establish the validity of this thesis they use a statistical approach. In particular, they look at the degree of correlation between these two variables, the shape of the distribution of individual price changes, and to the direction and degree of skewness of the distribution of individual price changes.

Vining and Elwertowski discuss Lucas' model which leads to the conclusion that the constancy of relative prices in neoclassical economics is translated into a constancy in the mode of variation in these prices. In the Lucas model the relative price (P_{it} - P_t) is a random variable and it is assumed to be distributed normally with mean zero and constant variance τ^2 and to be the same for all goods. The general price level, P_t, is likewise assumed to be normally distributed with mean $\boldsymbol{P_t}$ and variance σ^2. The variance of relative price changes turns out to be then, $2\tau^2$, or γ^2, which is also constant in this model.

Vining and Elwertowski compare graphically the standard deviation in individual price changes at time t, γ_t, and the overall inflation at time t. Two different measures of γ_t and inflation are constructed; one based on the Wholesale Price Index and another using the CPI. By examining the plots in both cases, they conclude that there are changes in γ^2 over time and that these changes are in close association with the degree of price instability, or σ^2. They observe high relative price change dispersion in the two episodes of general price instability at the beginning and end of the period, 1948-1974, and low relative price dispersion in the one episode of general price change stability in the middle of this period. As will be seen, Fischer(1981) reported similar findings for the U.S. economy for the period 1948-1980.

In addition, Vining and Elwertowski observe that the shape of the distribution of individual price changes, assumed in the Lucas article to be stable over time, is in fact highly variable and almost never of normal and infrequently of even symmetrical form. Using a measure of kurtosis, Vining-Elwertowski cannot accept the hypothesis of a normal distribution for any year. Using a measure of skewness, they find only three years in which price change distributions (P_{it+1} - P_{it}) accept the hypothesis of normality.

Vining and Elwertowski point out that the presence of skewness in the distribution of relative price changes is indicative of asymmetrical price responses in the economy. If the distribution of relative price changes is skewed to the right, possibly because of downward rigidity of price changes, then the mean of price changes will be greater than the mode or median price change. A negative skew implies that the mean (P_t - P_{t-1}) is smaller than the mode or median. With this in mind, Vining and Elwertowski find that, in general, if the inflation rate is climbing, then there is a positive skew, whereas the opposite occurs if the inflation rate is falling. They also find that as the inflation becomes less variable, the distribution of individual price changes becomes more symmetrical. This results are confirmed by Blejer (1983).

In one of the first studies that utilize a priori assumption about the relation between relative prices and inflation, **Parks (1978)** shows that changes in relative prices and ultimately the changes in relative price variability are related to supply conditions, changes in real income and the amount of unanticipated inflation. As discussed in section 2.1, he uses a multisectoral supply-and-demand framework and the assumption that suppliers use the same information and arrive at the same prediction.

His empirical analysis is for annual data for consumer goods from the United States (1929-1975) and Holland (1921-1939 and 1948-1964).

Relative price variability is measured as the weighted sum of squared deviations of the individual rates of price change around the average. Parks works with the Dutch data for a preliminary look at the behaviour of relative price variance and arrives at the conclusion that there does appear to be an association between the rate of inflation and the variance in relative price changes. A more complete test is done with annual U.S. data. Separate regressions were run for the prewar and postwar periods (1930-1941 and 1948-75, respectively and for the combined period), based on equation (2.5) from section 2.1.1.A. He finds that the series of price changes itself is non-stationary but the first difference of the series (DP_t - DP_{t-1}) appears random. This suggests that best predictor for DP_t is: $DP^e_t = \mu^e + DP_{t-1}$. The regression results based on the equation for VP_t show that, in each case, real income and unanticipated inflation enter significantly in both squared and linear form.

Although his model suggests no separate role for the actual (or anticipated) rate of inflation in determining relative price variance, Parks argues that if there are real costs associated with price changes, and if they vary across sectors, then there will be an association between these two variables. To test this hypothesis Parks estimates a second set of regressions in which DP^2_t is included. He finds evidence supporting a separate effect of the rate of inflation, but the evidence suggests that the effect is not as strong as the effect of unanticipated inflation. He points out that the empirical problem of determining whether there is a separate role for the rate of inflation is complicated by the apparent association between the rate of inflation and the movements in both real income and anticipated inflation.

Fischer's(1981) study for the United States covers the period 1931-1981. The measure of relative price change variability used is based on the weighted variance of market price movements around the inflation rate, as in Parks. Fischer addresses two problems with this measure. First, he notes that a problem with the standard measure of relative price change variability is that "it cannot distinguish between the changes in relative price variability that are appropriate for the optimal allocation of resources and those that are mistakes" (p.391). As will be seen, Neumann and Von Hagen (1991) will address this issue and propose that a measure of conditional relative price change variability be used to solve the problem. Second, Fischer notes that the degree of aggregation does not allow a test of whether misallocations associated with unexpected inflation in market clearing with misperceptions arise from excessive search. He suggests that to test this hypothesis it would be desirable to work with a time series dispersion of prices of the same good.

Fischer estimates two series of relative price variability, VAR8 and VAR11, calculated from eight and eleven components of the consumption deflator on a quarterly basis. The first series excludes energy and food commodities and the second series includes them. Using these two series and Parks'(1978) annual data, Fischer estimates regressions of the form:

$$VP_t = \alpha_0 + \alpha_1 DP_t + \alpha_2 |DP_t| + \alpha_3 \Delta DP_t + \alpha_4 |\Delta DP_t| + u_t \qquad (3.33)$$

$$VP_t = \beta_0 + \beta_1 DP_t^e + \beta_2 |DP_t^e| + \beta_3 DP_t^u + \beta_4 |DP_t^u| + e_t \tag{3.34}$$

where DP_t and $|DP_t|$ are the inflation rate and the absolute value of the inflation rate, respectively; and $DP^e{}_t$, $|DP^e{}_t|$, DP_{ut} and $|DP^u{}_t|$ are expected and unexpected inflation rates in actual value and absolute value. Expected inflation is generated as the prediction from a fourth-order autoregressive model and unexpected inflation then is estimated as the difference between expected and actual inflation in each period.

Fischer arrives at three important conclusions. First, looking at the graph of the series VAR8 and VAR11, he observes that during the 1970s energy and food shocks dominated the variance of relative price changes. Second, he finds the expected rate of inflation significant in the regressions and concludes that this rules out the view that anticipated inflation is neutral. He points out that if an inflationary shock takes time to have its effect on the economy, anticipated inflation could well be associated with increased relative price change variability. Third, after removing the effects of energy and food price shocks, unanticipated changes in money are associated with increased relative price change variability. Moreover, relative price change variability rises more when unanticipated inflation is positive than when it is negative. He relates this to the fact that prices respond asymmetrically around some inflation rate set on the basis of recent experience.

Hercowitz (1981 and 1982) studies the determinants of dispersion of relative prices using a version of Lucas' and Barro's partial information-localized market models (see section 2.1.1.B). In this extended model, different excess demand elasticities across commodities imply a relation between relative price variability and unperceived monetary growth. This association is tested with monthly data from the German hyperinflation era, 1921-23, a period of predominantly monetary disturbances, and with U.S. data for the period 1948-76.

Hercowitz's model predicts that relative price dispersion is related to exogenous shocks affecting the economy, in particular unperceived monetary injections, and to the variance of money shocks. The measure of price dispersion is constructed using data on a sample of 68 series of monthly averages of wholesale commodity prices. He obtains the following results from the data on the German hyperinflation (numbers in parenthesis are standard errors):

$$\underset{}{VP_t} = \underset{(0.008)}{0.038} + \underset{(2.9)}{16.8}(m_t^e - m_{t-1}^e)^2 - \underset{(9.8)}{18.5}\sigma^2_{mt} \qquad (2.35)$$

$$R^2 = 0.67 \quad DW = 2.2$$

The monetary shocks appear to have considerably explanatory power for relative price change variability. On the other hand, the coefficient of $\sigma^2{}_{mt}$ is negative, which suggests a dominant Lucas-type effect of the money variance on price dispersion, contrary to Barro's (1976) results. This implies, that the degree of dispersion associated with given shocks diminishes the higher their variance.

Hercowitz also tests if actual money growth and inflation are related to price dispersion. He points out that there is no rigorous theoretical justification for their inclusion in his model, but previous studies have been using them as explanatory variables. He finds no evidence supporting the inclusion of actual money growth, confirming the hypothesis that money affects relative prices only when it is unperceived. On the other hand, when he includes the acceleration of inflation[1] $(DP_t - DP_{t-1})^2$ the results suggest that there is a positive and significant influence of the inflation rate on the variability of relative price changes.

In a second study Hercowitz (1982) reports an empirical test of a price dispersion equation using U.S. post-war data. Money shocks are measured by the unanticipated money growth series estimated by Barro (1978). The series on price dispersion is computed using annual wholesale price indexes for the period 1948-76. The equation for relative price variability is derived from Hercowitz (1981), with the distinction that the variance of monetary shocks, σ^2_m, is assumed to be constant over time. There is also a modification to the previous model, an aggregate supply shock that affects equally all markets is introduced.

For the model, he estimates the following regression:

$$\begin{aligned} VP_t = {} & \underset{(0.002)}{0.009} - \underset{(0.027)}{0.011}(m_t^e - m_{t-1}^e)^2 + \underset{(0.036)}{0.065}(m_t^e - m_{t-1}^e)(v_t - v_{t-1}) \\ & + \underset{(0.029)}{0.054}(v_t - v_{t-1})^2 \qquad R^2 = 0.22 \qquad DW = 1.2 \end{aligned} \tag{2.36}$$

where v_t represents the real aggregate shocks. He points out that this term can be thought as, for example, changes in technology or in the availability of resources such as energy.

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[1] The acceleration hypothesis was postulated by Graham (1930) on his study of the German hyperinflation of the early's 1920's.

Contrary to what was found with the German data, these results amount to a rejection of the hypothesis that the magnitude of changes in monetary shocks positively affects dispersion of relative prices. Hercowitz suggests that "The difference in results may be related to the extreme magnitude of the monetary disturbances during that period (German hyperinflation), and to the apparently important effect of real factors--which directly affect relative excess demands--in the United States"(p.26).

Summarizing, Hercowitz finds a statistically significant correlation between unperceived money growth and price dispersion, and that the money variance turned out to have a negative coefficient which was only marginally significant, when he uses German data. In addition, he finds that the magnitude of changes in the inflation rate appears to have a separate correlation with relative price changes variability, although his model does not provide an explanation for this association. However, the effect of money shocks that his model predicts is not found when he uses U.S. data for the period 1948-76.

Cukierman and Leiderman (1984) presented and tested a theory for relative price variability for market-determined prices where there is also a sector whose prices are set directly by the government and disseminated promptly and widely throughout the economy. The model developed by Cukierman and Leiderman is an extension to Hercowitz's model, as discussed in section 2.1.1.B. In order to test their model, they used monthly data on the Israeli economy covering the period from 1966 to 1980.

Equation (2.24) from section 2.2.1.C was estimated by maximum likelihood and yields the following results:

$$VP_t^F = \underset{(4.23)}{0.0003} + \underset{(3.7)}{0.085}(m_t^e - m_{t-1}^e)^2 + \underset{(6.95)}{0.153}(g_t + m_{t-1}^e - Dp_t^c)^2$$
$$\underset{(2.71)}{0.141}(m_t^e - m_{t-1}^e)[g_t + m_{t-1}^e - Dp_t^c] \qquad R^2 = 0.19 \qquad (2.37)$$

where figures in parenthesis below regression coefficients are estimated t statistics. Actual money growth (ΔM_t) is decomposed into expected and unexpected components (g_t and $m^e{}_t$, respectively) assuming that money growth follows an AR(6) process.

The main difference with respect to Hercowitz's equation for relative price variability is the term ($g_t + m^e{}_{t-1}$). This term implies that in the presence of a controlled sector and some disparity in elasticities across *free goods*, lack of synchronization between the certain part of the nominal stock[2] ($g_t + m^e{}_{t-1}$) and the price of the controlled good $p^c{}_t$ will affect relative prices even within the group of *free goods*. When the government sets $\Delta p^c{}_t$ so as to make it equal to ($g_t + m^e{}_{t-1}$), this effect vanishes.

The results support the notion that the existence of a controlled sector may have important implications for relative price variability within the economy's free sector through the lack of synchronization

[2] Note that $\delta_t + \epsilon_{t-1} = \Delta(\delta_t + M_{t-1})$, which is the rate of change of the predictable part of the rate of change of the nominal stock plus the nominal stock at period *t-1*. Cukierman and Leiderman define $p^*{}_{ct} \equiv M_{t-1} + \delta_t$ as the neutralizing level of the controlled price good.

between nominal supply of money and the price of the controlled good. It is also evident that the goodness of fit of the model is not very significant. As Cukierman and Leiderman point out, "...the model's explanatory power for V_{Ft} (VP_{Ft}) is not impressively high. This suggests that in order to fully account for monthly variation in V_{Ft}, it is necessary to include in the analysis additional variables to those implied by the present imperfect-information model." (p.282)

2.3.2 Open Economy Studies

All the empirical studies summarized above, with the exception of Hercowitz (1981), have used data sets from relatively stable economies with low inflation. There are a few studies that have been done for economies with high and variable inflation. In addition, an important feature of most previous studies is their abstraction from open economy considerations. Two studies based on Latin American economies that take this feature into consideration will be summarized here. A third study, which takes into consideration an open economy is also included. The first study was done for the Mexican economy and the second one was based on the Argentinean economy, which has been characterized by particularly highly and variable inflationary process during the last twenty years. The third study investigates the relationship between conditional relative price variance and its determinants based on German data from the flexible exchange rate period, 1973-1985.

An extension of Parks' work was carried out by **Blejer and Leiderman (1981)** for Mexico for 1951-1976. The fundamental difference is that Blejer and Leiderman separate the (internationally) traded from non-traded goods. They tested empirically the relation between actual inflation, unexpected inflation and expected inflation and the variance of relative prices in a small open economy under a fixed exchange rate. They argue that when subsets of the commodities considered for the calculation of relative price change variability differ in their economic characteristic, as in the case of traded and non-traded goods, the use of partial indexes of dispersion is appropriate.

Blejer and Leiderman calculated VP_t for Mexico using annual time series from data for prices and outputs in 47 sectors. In order to test the effects of inflation on relative-price variability they estimated the equation of the form:

$$VP_{jt}^2 = a_j + b_j(DP_j)^2_t$$

for each sector, where j = T(traded) and NT (non traded).

They found that relative price change variability in the traded goods sector appears to be positively and significantly affected by actual inflation, while no significant relation is found for the non-traded sector. They also estimate a second set of equations of the form:

$$VP_{jt}^2 = a_j + b_j(E(DP_j))^2_t + c_j(DP_j - E(DP)_j)^2_t$$

for each sector, where E(DP) is the expected part of inflation and the unexpected is [DP - E(DP)]. To approximate the expected inflation they use a first-order autoregressive process. They found that for both set of goods only unexpected inflation has a significant and positive effect on VP_t.

Blejer and Leiderman then extent Parks model to a multimarket model of an open economy. As the market clearing mechanism operates differently for traded and non-traded goods, each sector is modeled separately. For the non-traded goods sector they arrive at a measure of relative price change variance of the form:

$$\begin{aligned} RVP_{NTt} = {} & \alpha_0 + \alpha_1(E(DP_T) - E(DP_{NT}))_t^2 + \alpha_2(DP_{NT} - E(DP_{NT}))_t^2 \\ & + \alpha_3(DM - DP_{NT})_t^2 + \alpha_4(E(DP_T) - E(DP_{NT}))_t \\ & + \alpha_5(DP_{NT} - E(DP_{NT}))_t + \alpha_6(DM - DP_{NT})_t + Z_t \end{aligned} \tag{2.38}$$

For the traded goods sector, they derive a similar equation to the one for non tradedgoods, with the subscripts alternating accordingly.

Although Blejer and Leiderman obtain satisfactory results for the non-traded goods sector, the results for the traded goods sector are not satisfactory because of the large standard errors of the coefficients in the equation corresponding to (2.38). To evaluate the determinants of the variability of relative price changes in the traded sector, they follow an alternative approach. They identify the U.S. as the major trading partner of Mexico and regress the VP_{Tt} on the overall variability of relative price changes of the U.S. (from Park's data). Their results are (standard errors in parenthesis):

$$VP_{Tt} = \underset{(0.00004)}{0.002} + \underset{(0.456)}{2.091} VP_t^{US} \qquad R^2 = 0.49 \qquad DW = 1.44 \tag{2.39}$$

The results suggest that variability in relative price changes in the U.S. explains almost 50% of the VP_{Tt} in Mexico for the period considered, implying that a substantial variation in the Mexican VP_t is due to exogenous factors which are outside of control of Mexican policy-makers.

Summarizing, when actual inflation is decomposed into expected and unexpected components, only the unexpected component appears to have strong effects on the within-sector variability of relative prices. The multimarket model provides a good explanation of the variability of prices of non-traded goods, whereas for the traded goods sector relative price variability was driven by an exogenous factor to the Mexican economy. Blejer and Leiderman conclude that an important implication of this finding is that there appears to be a mechanism of international transmission of relative-price variability, at least under fixed exchange rates.

Blejer's (1982) study is based on monthly observations of Argentina's CPI for the period 1977:4-1981:7. He considers the links between monetary variables and fluctuations of relative prices and discusses the effects of external-sector developments on variability of relative price changes. First, Blejer follows a statistical approach to investigate the association between inflation and the variability of relative price changes, similar to the approach of Vining-and Elwertowski.

Second, he studies this association with a theoretical approach, mainly based on previous studies and on Hercowitz model.

In a preliminary discussion about the characteristics of the data Blejer estimates an equation of the form: $DIF_t = \alpha + \beta DP_t$, where DIF is the difference between the highest and lowest rates of individual price changes and DP is the inflation rate. He finds that the span over which individual prices fluctuated is directly related to the level of inflation and suggests that an explanation for this relation is that industries and sectors may differ in their speed of adjustment to nominal shocks.

Blejer uses a chi-squared test to determine whether the distribution of relative price changes is normal, and he finds that the acceptance depends on the length of the period of observation. In particular, if one uses the month as a unit of observation then the normality assumption is rejected in 27 months of 50. On the other hand, if one uses annual data, in only one out of fifty cases is the normality assumption rejected. In addition, he regresses the degree of skewness on both the level and change in inflation rates, obtaining a strong and positive association between these variables.

According to Blejer the reason normality depends on the period of observation is that in the very short run individual prices do not fully adjust to the various shocks because there are certain costs to do so. If many commodities are subject to these adjustments costs, then only a few commodities will have had a change for any given month. This in turn implies a non-normal distribution for individual price changes. For a longer period of observation more individual prices should be responsive since they would have had enough time to adjust to the initial shock. As a consequence, a normal or at least a symmetrical distribution will be observed.

In the second part of the study, Blejer assumes a direction for the causality between the inflation rate and the variability of relative price changes. Blejer constructs an alternative index to measure relative price variability, since there are some problems with the second moment of some non-normal distributions (the sample standard deviation is not stable and does not converge upon increases in sample size). His proposed index has the form:

$$DR_t = \frac{1}{(n-1)} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (w_i + w_j) \left| (DP_i - DP_j)_t \right| \tag{2.40}$$

where the measure of dispersion is independent of the central values of the distribution. DP_i is the rate of inflation for commodity i and w_i is the share of commodity i in the CPI.

Blejer considers that in a country like Argentina it is plausible that domestic price variability is affected by the behavior of foreign prices and other external sector variables. For this reason he includes the real exchange rate as one of the determinants of relative price change variability. He consider two specifications. First, based on previous studies, he estimates equations in which relative price change variability is a function of expected inflation, $DP^e{}_t$, unexpected inflation, $DP^u{}_t$, changes in real money balances, $(DM_t - DP_t)$, and real exchange rate, RE_t. In these regressions the dependent variable will take the values of DR_t or

VP_t, (the latter the standard measure of the variance of relative price changes). Unexpected inflation is measured as the difference between the actual inflation and the 30-day nominal interest rate set at the end of the previous month. The results support the hypothesis that inflation and relative price variability are linked only if inflationary developments are unexpected:

$$VP_t = \underset{(0.67)}{-5.508} + \underset{(4.16)}{1.521}(DP_t^u)^2 + \underset{(1.46)}{1.091}(DM_t - DP_t)^2 + \underset{(2.02)}{6.281}RE_t \qquad (2.41)$$

$$R^2 = 0.367$$
$$DW = 2.10$$

For the second specification, following Hercowitz model, Blejer solves for the aggregate rate of inflation in terms of the rate of money growth and then obtain a specification relating relative price change variability to unexpected monetary changes. The results indicate that only the unexpected component of the rate of monetary growth increases the degree of price movement dispersion:

$$VP_t = \underset{(0.16)}{-1.584} + \underset{(2.38)}{139.78}DM_t^u + \underset{(2.17)}{10.60}RE_t - \underset{(1.25)}{113.62}DM_t^e \qquad (2.42)$$

$$R^2 = 0.25$$
$$DW = 2.08$$

where $DM^u{}_t$ and $DM^e{}_t$ are the unexpected and expected monetary change, respectively, both generated from a second order autoregressive process with seasonality factors at the sixth and twelve lags.

In summary, Blejer arrives at four important conclusions. First, prices of individual commodities have fluctuated over a much wider range than the aggregated CPI in Argentina. Second, individual price changes appear to be distributed asymmetrically on a monthly basis but symmetrically on an annual basis. And third, relative price change variability is related to the magnitude of nominal shocks; only the unexpected components of inflation and monetary growth have explanatory power in the equations. Fourth, the real exchange rate also has a significant effect on relative price change variability.

Neumann and Von Hagen (1991) tested empirically the relation between the conditional variance of relative prices and the conditional variance of aggregate shocks using German data for the flexible exchange rate era, 1973-1985. Their study differs from the previous studies because they distinguish between expected and unexpected relative price changes. They argue that the use of observed variability to measure conditional variances relies on the unrealistic assumption that all relative price changes take the private sector by surprise.

Their analysis is based on the open economy version of the multimarket model. They assume that there are three aggregate exogenous shocks that have an impact in all domestic markets simultaneously, a domestic money supply shock with variance σ^2_{Mt}, a foreign nominal shock with variance σ^2_{*t}, and a real exchange rate shock with variance σ^2_{qt}. All variances are allowed to change over time. They also assume a rational expectations approach with imperfect information. The only output price an individual can observe is his own local price and all agents observe the current nominal exchange rate and the world market price of imported inputs.

Neumann and Von Hagen objective is to test two hypothesis. The first hypothesis is that the conditional relative price variability is a positive function of the variance of the domestic monetary shock, the variance of the foreign nominal shock, and the variance of the real exchange rate. The second hypothesis is that an increase in conditional relative price dispersion lowers aggregate output supply. They test these two hypothesis using 14 West German indices of producer's prices of manufactured goods.

Following Engle's (1982) autorregresive heteroskedasticity (ARCH) approach, Neumann and Von Hagen model and estimate time-varying conditional variances for individual prices and the aggregate variables. Using these results they determine that reject the hypothesis of the conditional relative price change variability does not depnd on the variances of aggregate shocks. With respect to the effects of conditional relative price variability on output, Neumann and Von Hagen also find evidence that increasing uncertainty about domestic monetary policy and external economic conditions, measured as conditional relative price change variability, has a negative impact in long-run output.

2.3.3 Summary and Conclusions

The empirical papers reviewed in this chapter can be grouped into two categories; those studies done considering a multimarket model with open economy and those that do not consider this feature. Parks(1978) and Fischer(1981) found that anticipated inflation was an important determinant of the variability of relative price changes. These two studies were done with data from the United States, the Netherlands and the United Kingdom, three relatively stable economies.

On the other hand, Blejer (1983) and Blejer and Leiderman(1982) found for Argentina and Mexico inflation increases relative price change variability only when it is unexpected. They also found strong support for the hypothesis that foreign relative price variability affects domestic variability. This latter hypothesis is also supported by Neumann and Von Hagen's(1990) empirical study for Germany. Hercowitz's (1981) study is done with data from Germany from the hyperinflationary period. He points out that his theoretical model does not consider important facets of hyperinflation. In particular, he refers to the fact that it ignores the foreign exchange market and the sustained divergence between internal and external values of the mark, which are related to relative prices.

Vining-Elwertowski's study concentrates on the relationship between the variance in relative price changes and the *variance* in general price changes, (inflation instability) rather than inflation *per se*. This aspect is also discussed in Neumann and Von Hagen (1990), since they relate the variance of relative price changes to the variance of domestic and foreign nominal and real shocks.

From these articles one can conclude that the "standard" measure of relative price variability presents some problems. Blejer(1983) find that relative price changes were not normally distributed, so he propose an index for VP_t that is independent of the central values of the distribution that is a weighted variation of the Gini mean difference index.

A more serious critique of the standard measure is provided by Neumann and Von Hagen (1990). They addressed the problem with the standard measure of relative price change variability in terms of theoretical implications, i.e, it does not distinguish between expected and unexpected relative price changes. Fischer (1981) and Hercowitz (1981) discuss problems with the interpretation of this dispersion measure. Fischer(1981) does not assumes anything about the information set available to the economic agents, whereas Neumann and Von Hagen assumed a multimarket model with imperfect information, and therefore conclude that they should test whether the variance of conditional relative price forecast errors is related to the aggregate shocks.

Hercowitz (1981) also suggests that there may be some problems with measurement of relative price dispersion over long periods of time. In particular he notes that: "...long-run differential technological changes will cause prices to disperse over time. One would like to filter out such effects, because the focus here is on the short-run distortions caused by incomplete current information." (p.335)

It is important to notice that Parks assumes a multimarket model with perfect information and although his model predicts no role for unanticipated inflation, he tests for the effect of this variable on relative price changes variability and finds evidence supporting this relation. Likewise, Hercowitz's (1981) model does not justify a role for actual inflation, but he finds statistical evidence supporting the hypothesis of a positive correlation between price dispersion and the acceleration of inflation.

The results from these empirical studies suggest that the implications of the Equilibrium Misperception models stand a better chance of being be detected in countries with high and variable inflation. Hercowitz uses the same model with two different data sets and obtains opposite results. The implication of his model are supported when he uses the German data, whereas his model is not validated when he uses U.S. data.

In terms of the validity of the econometric results some of the studies were done with a rather small sample, which rises the questions of how serious the results are. For example, Parks' (1981) study is based on 43 observations, Blejer and Leiderman's (1982) on 26 observations. Blejer's (1983) study for Argentina includes the real exchange rate as a determinant of relative price change variability, but there is no discussion about the exchange rate regime of the economy. In contrast, Neumann and Von Hagen's (1990) analysis is for the flexible era exchange rate in Germany; whereas, Blejer and Leiderman's (1982) study is done for a fixed exchange rate period in Mexico. Both studies arrived at the same conclusion: foreign relative price variability increases the domestic variability.

CHAPTER III

THE PERUVIAN ECONOMY: 1976-1990

3.1 Introduction

Peru is a small and moderately open economy with a long history of heavy dependence on mineral exports for its prosperity. Well endowed in natural resources, Peru is now the world's largest producer of silver and fifth largest producer of copper. In addition, it has considerable fishing potential and hydrocarbon resources. Agriculture and mining lost their predominance in the economy due to the import substitution model that was followed during the late 1960s, which gradually made industry the mainstay of the economy.

In terms of economic history of Peru, two stages can be distinguished over the last three decades. The first stage spans the years, 1963–1975, and was characterized by an industrialization through the import substitution program, which began in 1963 during President Fernando Belaúnde's first government and was intensified during 1969–1975. The second stage has been characterized by macroeconomic disorder and the complete lack of a development strategy, and has lasted from 1976 to the present. One of the symptoms of this economic chaos has been high inflation which was accompanied with low, and during some years negative, real growth.

A brief summary of the Peruvian macroeconomic background is presented in this Chapter. This summary has been organized in terms of administration periods and covers the period 1976-1990. The focus is to present a succinct description of the Peruvian economy in the last fifteen years in terms of the links between macroeconomic policy, high inflation and real growth. This will provide a basis for empirical analysis of the relationship between inflation and relative price variability in Chapter IV.

3.2 Crisis, Adjustment and Export Boom: 1976-1980

When Francisco Morales Bermúdez took over the presidency in 1976, he stated that the second phase of the military government had started. This phase was supposed to introduce some corrections to the major reforms started by Juan Velasco, without deviating from their original objectives; emphasis was also placed on increasing efficiency, promoting exports and increasing domestic savings. However, pressed by the urgent need to face the existing serious macroeconomic disequilibria, the government abandoned many of the initial objectives.

The period 1976-1980 can be divided into two parts. The first covers the first 33 months of Morales Bermúdez's administration and is characterized by a succession of failed stabilization attempts without a substantive change in economic policy.

Since 1976 the government attempted to change the expenditure and production pattern of the economy by implementing an exchange rate devaluation and by the granting subsidies to the "non-traditional" exports. Inflation in 1976 reached 44.7%, the highest rate of the century until that time. The growth of GDP decelerated, and an absolute contraction in GDP was recorded in 1977.

Table 3.1 Main Economic Indicators, 1976-1979.

Indicator	*1976*	*1977*	*1978*	*1979*
GDP (change in real terms)	1.6	-1.1	-2.1	4.7
Inflation rate	44.7	32.6	73.7	66.7
Liquidity in domestic currency (nominal change)	15.6	27.1	42.1	81.6
Monetary base (nominal change)	48.1	24.4	50.7	106.0
Nonfinancial public sector deficit (% of GDP)	8.8	8.6	5.4	1.1

Source: Own calculations based on Webb and Fernadez Baca (1991)

During the first half of 1978, the GDP continued to decrease, inflation accelerated and the external situation worsened. The second stage --the transition towards democracy-- began in May 1978, with the implementation of a severe stabilization program which rapid success was facilitated by a favorable external environment. This program was followed by the beginning of a process of import liberalization which comprised several expenditure reducing and expenditure switching measures and managed to renegotiate the service of foreign debt.

On the inflation front, results were also positive; the annualized inflation rate dropped from 70.6% in the first half of 1978 to 41.8% in the second half of that year. The adjustment, however, was accompanied by a decrease in GDP and by a fall in real wages. The recessionary cost of this program was relatively small, due to an export boom, similar to the one that helped the successful stabilization episode of the late 1950s. The terms of trade increased by 34.3% in this year, improving the balance of payments and public sector revenues. Despite an 11% increase in government expenditure, higher tax and public sector enterprise revenues made it possible to reduce the budget deficit by more than 5 percentage points of GDP, to the equivalent of only 1.1% of GDP.

In terms of growth and inflation, the 1976-79 period contrasts sharply with the preceding ones. On average, GDP grew by only 0.7% (in per capita terms, this represented a drop of 1.9% a year). The average inflation rate of the period was 48.4%, and, in 1979, the foreign debt of the public sector was almost double that of 1975.

3.2 Populism and liberalization: 1980-85

The beginning of the 1980s marked the return of democracy with the election of Fernando Belaúnde as President of Peru. His second administration (July 1980-July 1985) received a relatively stable macroeconomic situation. The stabilization program and the export boom of the late

1970s had improved substantially the public sector's finances; and the terms of trade and the real exchange rate, although lower than in 1979, were at fairly high levels. However, despite the exceptionally favorable export prices of 1980, the service of foreign debt already represented 37.1% of export earnings.

While the new administration emphasized the need for reducing inflation, liberalizing price controls and increasing the openness of the economy, in practice the authorities implemented an expansive fiscal policy and a passive (or accommodating) monetary policy. This policy mix combined with the use of the exchange rate as an anti-inflation instrument, caused a strong appreciation of the real exchange rate. This combination of policies was not consistent with the objective of opening the economy, or with the goal of reducing inflation.

At the end of the first two years of these measures there were some symptoms of macroeconomic imbalances. The budget deficit rose to 4.7% of the GDP in 1980 and 8.4% in 1981. In 1981 the trade balance turned negative and inflation increased due to the elimination of price controls. The situation was made even worse by the marked increase in external interest rates and the drop in the international prices of the main exports. The government was able to finance these disequilibria because it inherited a high level of international reserves and because of external resources were available after the second oil shock of the 1970s.

In January 1982 the trade liberalization process was discontinued. The budget deficit increased to 9.7% of GDP. The export boom had officially come to an end. The serious imbalances in the economy were aggravated in 1983 by a series of natural disasters (floods in the north, droughts in the south and changes in the maritime conditions) that had a tremendously negative effect on domestic production, particularly that of tradeable goods. Coupled with a decrease in aggregate demand, these events led to an unprecedented recession (GDP fell by 12.9% in 1983) and caused inflation to climb to three digits for the first time in the country's history. This, in turn, caused the public finances to deteriorate even further, to the point that the deficit of the Non-Financial Public Sector reached 12.1% of GDP in 1983.

Table 3.2 Main Economic Indicators, 1980-1985.

Indicator	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*
GDP (change in real terms)	5.4	5.3	0.1	-13.2	4.6	1.7
Inflation rate	59.2	75.4	64.5	111.1	110.2	163.4
Liquidity in domestic currency (nominal change)	75.2	78.6	53.0	80.1	105.6	220.4
Monetary base (nominal change)	76.2	47.2	17.1	96.8	92.7	530.6
Nonfinancial public sector deficit (% of GDP)	4.7	8.4	9.7	12.1	6.2	2.4

Source: Own calculations based on Webb and fernandez Baca (1991).

A stand-by program with the IMF allowed the economy to continue to have access to external resources during the first half of 1983. However, Peru's inability to comply with the targets of the IMF program in mid-1983 made the country finally face the foreign debt crisis that had been affecting the rest of Latin America since 1982, and forced a more severe adjustment. In April 1984, a new agreement was signed with the Fund. The magnitude of the adjustment was insufficient to meet the targets of the new IMF program. The Belaunde administration started to postpone servicing the foreign debt.

Belaunde's government continued with its adjustment program and managed to reduce the fiscal deficit to 2% of GDP in 1985, as well as to obtain a strong real depreciation of the exchange rate (which increased by 27% between 1983 and 1985). In terms of output growth, the cost of the adjustment program was high. Following the sharp drop in production in 1983, the per-capita GDP grew by only 2.5% in 1984 and 0.4% during the first half of 1985. During the second Belaúnde administration per-capita GDP fell an average of 3.9% a year, bringing with it a consequent increase in the level of absolute poverty in the country.

3.4 The Heterodox Program: 1985-1990.

When the Garcia administration took office in July 1985, the economy had not yet recovered from the 1983 output plunge and the country suffered unremitting stagflation. Unemployment was still high at 11.8%, unutilized industrial capacity was estimated at 50-60%, total external debt was 92% of GDP, and growth projections for GDP for 1985 were negative. In addition, the rising inflation (projected at 200%) had translated into progressive financial instability, with dollarization of bank deposits accounting for 58% of total internal liquidity. However, efforts to stabilize the economy undertaken by the Belaunde Administration in 1984-85 left to the new government a strong international reserve position and a competitive real exchange rate.

Within this context the new administration sought in the "Heterodox Model" a theoretical framework to initiate an economic recovery. Heterodox measures were first adopted by Argentina in June 1985, by Peru in August 1985 and by Brazil in February 1986. In Argentina and Brazil, heterodox policies were conceived as short-term programs aimed at controlling inflation. In contrast, the heterodox program in Peru claimed to go beyond stabilization and combine short-term policies with a new long-term development strategy that would include redistribution and restructuring. In fact, the economic policy adopted by Garcia's administration had the effect of altering Peru's economic structure.

In the face of an economy with high unemployment and high levels of unutilized capacity in many sectors, heterodox economists claimed that the argument that inflation resulted from excess of demand did not make sense. Instead, they attributed inflation to increasing costs resulting from devaluations, rising interest rates and modern sector price formation in response to declining demand. They argued that the fiscal deficit was not inflationary, but even recessionary, since the deficit adjusted for external debt service payments showed a surplus.

Looking for a quick economic recovery, consumption demand was stimulated by increasing real wages, tax rate were cut and exonerations permitted, and state enterprises' prices and tariffs were frozen. Domestic industry was protected by controlling imports and agricultural subsidies and preferential credit to the agriculture were expanded so as to improve the standard of living of the rural poor. In addition a multiple exchange rate and price control system was implemented.

In order to contain inflation, the exchange rate was frozen for one year, addressing inflationary expectations. To finance the program the government relied on a reduction of external debt payments. In his inauguration speech, President Garcia announced an unilateral limit of 10% of the value of exports for external debt-service payments.

The Garcia program was called an "Emergency Plan" and was designed for one year. Instead it lasted from August 1985 until December 1986. Initially, the program brought forth very impressive results. Nominal wages were increased 25 percent in August 1985 and from then on periodic wage raises were granted approximately every four months. As a result, real wages increased by 34 percent between August and December 1986. Tax cuts culminated in a reduction in the sales tax rate from 11 to 6 percent in February 1986.

The combination of selective price controls and demand reactivation led to a rapid increase in GDP and a substantial decline in the inflation rate. Total GDP expanded 9.5% in 1986, agriculture by 3.8%, manufacturing by 15.9%, construction by 24.1% and trade by 13.3%. The driving force behind this response was the 13.3% increase in consumption expenditures, which account for three fourths of GDP. Demand for consumption goods increased as a result of "dedollarization" of the economy and of growing incomes. With the price freeze, inflation declined from 200% in the twelve month period before the freeze to 63% in 1986.

While the positive domestic results of the heterodox program were impressive, they were combined with increasing financial and external imbalances. International reserves were declining, the real exchange rate was increasingly overvalued and the fiscal deficit more than doubled. These distortions were threatening the achievements of the first phase of the program. The increase in aggregate demand not only reduced excess capacity in some productive sectors, but at the same time led to a considerable increase in imports[1]. Meanwhile, exports declined in 15 percent. The trade surplus of $1,172 million in 1985 become a $16 million deficit in 1986.

Table 3.3 Main Economic Indicators, 1986-1990.

Indicator	1986	1987	1988	1989	1990
GDP (change in real terms)	10.8	9.7	-7.4	-12.4	-2.4
Inflation rate	62.9	114.5	1,722.3	2,775.6	7,649.7
Liquidity in domestic currency (nominal change)	99.2	115.3	440.3	2,400.4	3,496.9
Monetary base (nominal change)	68.9	111.0	438.2	1,783.3	5,152.2
Nonfinancial public sector deficit (% of GDP)	4.9	6.7	6.9	6.6	2.3

Source: Own calculation based on Webb and Fernandez Baca (1991).

The central government deficit increased from 2% of GDP in 1985 to 3.5% in 1986 and the deficit of the nonfinancial public sector grew from 2.4 percent in 1985 to 4.9 in 1986, as a consequence of the freeze of public sector prices. The real exchange rate appreciated by 44 percent between July 1985 and October 1987.

[1] Peruvian manufacturing is highly dependent on imported inputs and technology; approximately 33 percent of inputs consumed and 70 percent of industrial equipment used are imported.

In 1987, the economy kept growing but at a lower rate, 9.7%. Several factors seemed to contribute to the decline in the growth of GDP. Some key economic sectors, such as steel, oil refining, chemicals, paper and electricity, neared full-capacity utilization (Thorp, 1988). This not only limited the growth of their own production, but also created constraints to growth in other sector through output-input dependencies. In addition, real aggregate demand experienced a slowdown, resulting from an acceleration of inflation and lower real wage increases. Inflation, although strongly repressed by price controls, accelerated once more and registered a 114.7% increase in the price level.

During 1987-88 several adjustments to prices and tariffs were introduced, but they lagged considerably behind inflation, depressing relative prices of traded goods. By contrast, wage increases continue to be granted regularly. In July 1987, commercial banks, finance firms and insurance companies were nationalized. The government justified this measure on the grounds of democratizing credit allocation and breaking the links between industrial groups and financial institutions. At the same time the government issued a low interest "mandatory bond" that Peru's more profitable firms were required to purchase. These two events marked the reversal of business confidence and precipitated the inconsistencies of the heterodox program into an open crisis.

On the external front, exports continued to show a poor performance in 1987, stagnating in dollar terms, despite drastic exchange rate adjustment and better copper prices. By contrast imports increased by 15% as a result of the expansionary demand management. The current account registered a deficit of 5% of GDP. Despite the announced 10% limit on external debt services, the actual debt service ratio was close to 19% in 1986 and 13% in 1987 (Memoria, Banco Central de Reserva (1988)).

By the beginning of 1988, severe adjustment become inevitable. The government choose a strategy of "selective growth", supporting agribusiness activities, production of inputs for basic consumption goods, and strategic supplies. Other activities were considered nonessential. Trying to prevent the large negative social impact of a one-time adjustment of key prices, the administration adopted a gradualist approach with major policy packages in March, June, September and November. Components of the "packages" were devaluations, increases in controlled and public prices and interest rates, and wage increases lagging behind the rate of inflation.

In March 1988, public sector prices and tariffs were increased in the range of 22 to 50 percent and wages in the range of 40 to 60 percent. Furthermore, it was announced that these adjustments would be followed by a 120-day freeze. However these adjustments did not compensate for the rising inflation rate that reached 1,722% by the end of the year. For example, the real price of the gasoline in August 1988 was only one third of the price in July 1985. This further aggravated the public finance disequilibrium.

In September 1988, in a desesperate attempt to solve the economic problems, the government introduced still another severe adjustment program. To eliminate the public sector deficit, it increased controlled prices by as much as 300 percent, unified exchange rates (which represented an average devaluation of 75%) and introduced a temporary tax on exports. At the same time, the Central Bank announced a restrictive credit policy and increased interest rates. However, the corrective effect of these measures was undermined when the government decreed a wage increase, 150% in minimum wage, and announced that within 10 days all prices were to be frozen for 120 days. The result: private firms increased their prices abruptly, and monthly inflation in September reached 114%.

The September package differed from the others not only for the magnitude of the price adjustments but because of the Central's Bank restrictive credit policy. The combination of policies decreased real money balances and caused a significant contraction in credit. However, the public sector deficit was not eliminated and the initial increase in controlled prices was not sufficient to accommodate the devaluation due to unifying the exchange rates. Although the restrictive credit policy help to reduce aggregate expenditures, the adjustment in the public sector was unsustainable and insufficient, thus crowding out private sector activity (Paredes, 1992). Tight monetary policy and the failure to realign relative prices created a recession and inflation was not reduced. By the end of 1988 GDP declined by 7.4%.

In 1989, the situation deteriorated even further. Hyperinflation and severe recession persisted. A new economic program was introduced with a timetable with progressively smaller adjustments in the exchange rate, the price of fuels and public services and the minimum legal wage was established for February through May 1989. Despite these measures inflation was not controlled. The cumulative effect of recession, hyperinflation and lagging prices of public goods and services eroded fiscal revenues. By the end of 1989, GDP decreased by 12.4% and the consumer price index rose 2,775%. The only positive element was a substantial increase in international reserves resulting from the drastic reduction in imports due to the severe recession. The severe recession caused per capita income to drop to levels recorded twenty-five years before.

During the first half of 1990, the burden of "controlling" the free exchange rate[2] was placed on monetary policy. Credit to the private sector was reduced by an increase in the reserve requirements on deposits. Reserves continue to decline, to $600 million, $1 billion less than in August 1989. After 12 consecutive months with an inflation rate of around 30% per month, inflation rose again in June 1990, reaching 43 percent. At the same time, the free exchange rate was 200% over the official rate. By late July, inflation was at 6 percent per day. By the beginning of 1990, the Peruvian economy was confronting hyperinflation, serious distortions in relative prices, recession and unemployment. These problems were further complicated by an increase of the social violence which had started in early 1980s.

[2] The Central Bank was providing dollar loans to exporters and selling promissory dollar notes to importers in an attempt to depress the free market exchange rate.

3.5 Summary and Conclusions

As was presented in this Chapter, by 1990 Peru's economy was in total disarray. This was not a sudden development. In per capita terms the economy has not grown since 1975, and the crisis deepened by the end of the 1980s. These fifteen years have been characterized by accelerating inflation, periods of deep recession, recurrent balance of payments crises, and a progressive impoverishment of a significant part of the population.

During these fifteen years one can observe two periods in terms of inflation. Until 1973 inflation rates were relatively low, averaging 7% per year. From that period on, inflation rose abruptly, without returning to the previous levels. During 1973-1978 inflation rate fluctuated between 5 and 42%. From 1979 on inflation accelerated until it reached levels considered hyperinflationary during the late 1980s.

The military government policy was characterized by price controls and freezing key prices. During the second phase of the military government, 1978-1980, the price system was more flexible. By 1980, the return to the democratic system coincided with the liberalization of the prices of most the goods in the consumption basket, but the government continued to control some key prices such as gasoline, tariffs, etc.

Finally, with the heterodox program, despite the attempts to control inflation by allowing controlled prices to rise slowly and real exchange rate to appreciate, the inflation rate not only remained high but reached hyperinflationary during the late 1980s.

CHAPTER IV

INFLATION AND RELATIVE PRICE VARIABILITY IN THE PERUVIAN ECONOMY

4.1 Introduction

As shown in Chapter III, inflation has been a major problem in the Peruvian economy since 1980. Several policies were launched in order to control and reduce inflation and changes in policy regimes created uncertainty about the price level. In theoretical models this make it difficult for economic agents to distinguish between aggregate and relative shocks. Due to their lack of information they may partly misperceive price level changes as relative price movements and, consequently, adjust supply in response to purely nominal shocks. Thus, inflationary shocks may have real effects because they distort relative prices.

The empirical relevance of this hypothesis is still open to question, as discussed in Chapter II. This chapter sheds some additional light on the relationship between relative price variability and inflation. An analysis of relative price variability in Peru is carried out using two different models.

The first model is based upon a time series of observed relative price variability and unexpected and expected inflation. This model assumes that all relative price changes take the private sector by surprise. This model follows many previous studies that have used the observed relative price variability as a dependent variable.

The second model assumes that the conditional variance of relative price forecast errors on local output markets is positively related to the conditional variance of aggregate shocks. For this purpose a series of conditional variances of relative prices, inflation and other variables are estimated and used for the regression model. The variances are estimated using Engle's (1981) ARCH process regression model.

The order of presentation of this chapter is as follows. Section 4.2 describes the data used and presents a brief discussion about the goods include in the construction of the consumer price index. Section 4.3 presents a descriptive preliminary analysis of the data. Section 4.4 describes the econometric techniques used for the estimation of the models. Section 4.5 presents the empirical modelling and estimation and presents the results of the regressions carried out. The last section contains a summary and conclusions of the chapter.

4.2 Description of Data

The study is based on monthly observations of Peru's consumer price index (CPI) for the period 1979:12–1988:07. CPI by components prior to 1979:12 is not available on a monthly basis. Monthly data is chosen because it reduces the incidence of real changes and relative price variability is not lost in time aggregation. The sample period ends in July 1988 just prior to the severe adjustment measures taken in September and the period of hyperinflation that followed.

A monthly index of the 169 components of the CPI is published by the **Instituto Nacional de Estadistica** (INE) along with the aggregate index. For the purpose of this study, the 169 categories are aggregated into 32 components.[1] Table 4.1 shows the commodity classification and the correspondent weighs.

The series of relative price variability and inflation are constructed using 1979 as the base year. Inflation is calculated using the end of period price index. Observed relative price variability is based on the variance of individual prices changes around the mean.

During the period of analysis some key prices in the economy were controlled by the government. Prices of gasoline, rent, transportation and communication services, which represent about 24% of consumption expenditure, have been under control for the whole period. In particular, the heterodox program heavily applied price controls among its policies to prompt an economic recovery[2]. Under this program, market forces determined the prices of only about one-quarter of the items that consumers buy.

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[1] The list of categories is presented in an Appendix.

[2] A table in the appendix provides an overview of the categories and price setting mechanisms established during Garcia's administration.

Table 4.1 Consumer Price Index Categories

Categories	Weight	Categories	Weight
I. Food, beverages and Tobacco	**38.09**	**IV. Health**	**2.52**
1.Breads and Cereals	6.77	18.Medicine	1.28
2.Meats	11.03	19.Therapeutic Equipment	0.17
3.Diary	4.54	20.Physician services	0.74
4.Oils	2.02	21.Hospitalization expenses	0.17
5.Fruits and Vegetables	8.45	22.Health insurance	0.16
6.Coffee, Sugar and Tea	2.11	**V. Transportation and Communication**	**11.99**
7.Seasonings	1.41	23.Vehicles	1.49
8.Beverages and Tobacco	1.76	24.Gasoline	2.00
II. Clothing and Shoewear	**7.33**	25.Transport services	5.64
9.Clothing and Fabrics	5.16	26.Communication services	2.86
10.Shoewear	2.17	**VI. Entertainment and Education**	**16.53**
III. Housing	**22.55**	27.Entertainment	1.25
11.Rent	12.35	28.Books, newspapers and magazines	1.30
12.Electricity	3.22	29.Education	2.69
13.Furniture	1.57	30.Personal care	2.60
14.Household Goods	1.50	31.Food and beverages (restaurants)	8.69
15.China	0.21	**VII. Other**	**0.99**
16.Repair and Maintenance	2.14	32.Other	0.99
17.Housekeeping	1.56		

Source: Own construction based on consumer's basket published by Instituto Nacional de Estadistica.

In order to analyze the effects of inflation on relative price variability, the commodities with controlled prices are eliminated from the sample. Inflation series are constructed based upon the CPI including the whole sample of commodities, whereas relative price variability is constructed using the commodities that were not controlled during the whole period of analysis. Having a "pure" price index without any good which price is controlled by the government is difficult because of aggregation problems, but the basic goods that were controlled are excluded to obtain a good approximation.

4.3 Preliminary Analysis of Data

There is substantial evidence indicating that the inflationary process is not neutral with respect to the structure of relative prices. A first step in order to find out if the behaviour of inflation and relative price variability validates this hypothesis for Peru is to look at time plots of the variables. The figures presented below follow the same periodization as in Chapter III, each one covers different administrations.

The monthly rate of inflation for the period 1976-1980, of the Morales Bermudez administration, is plotted in figure 4.1. Inflation is measured as percentage change of the monthly aggregate price index. During this the average monthly inflation was 3.75%, fluctuating from

0.57% in June 1976 to 13.72 in January 1976. Annual inflation in 1979 reached the highest rate, 66.7%, after failed stabilization attempts.

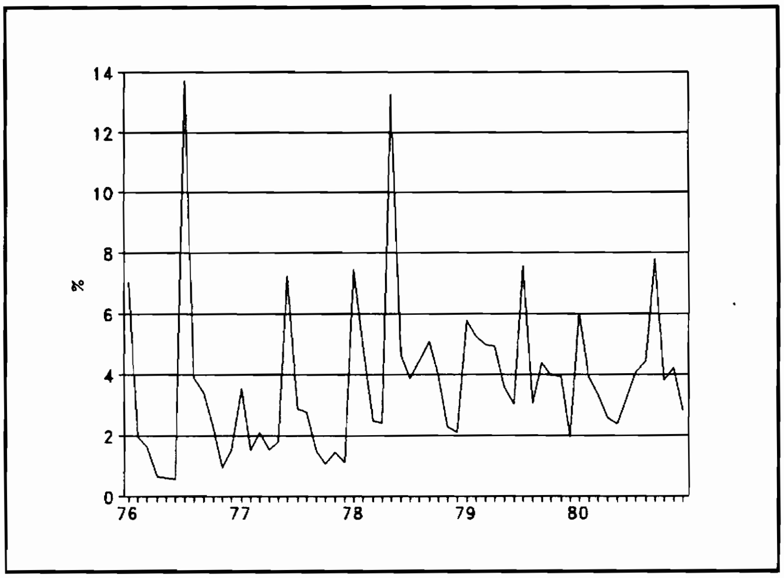

Figure 4.1 Monthly Inflation Rate 1976-1980

During 1980-1985, period of Belaunde's administration, the average monthly inflation rate increased to 5.86 and continue to fluctuate over a significant span, as shown in Figure 4.2. The highest rate of inflation was 13.70% in January 1985 and the lowest 2.73% in November 1985. In 1981, when price controls were eliminated, inflation increased sharply and in 1983, the year of natural disasters, annual inflation surpassed for the first time the three digits. At the end of this period inflation was not only increasing rapidly, it also became more volatile.

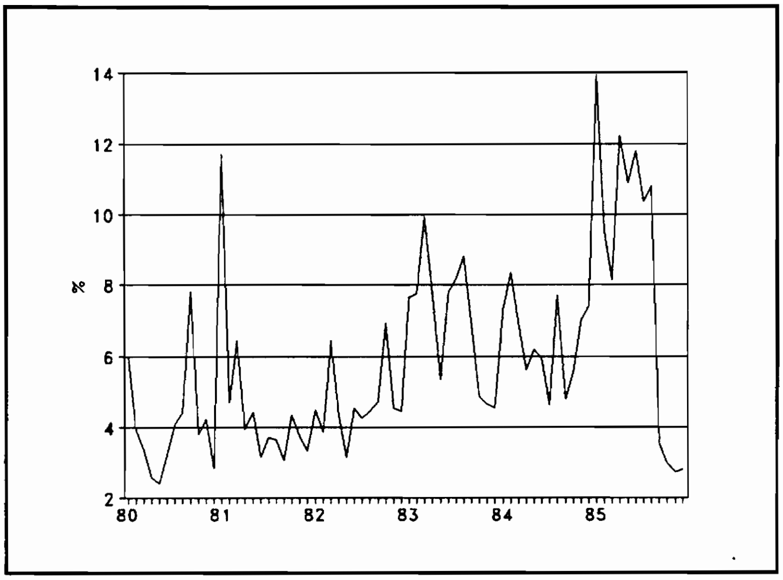

Figure 4.2 Monthly Inflation Rate 1980-1985

At the end of the 1980's the peruvian economy experienced not only the highest levels of inflation but price changes also fluctuate over a wider range. The average inflation rate for the years 1985-1990 increased dramatically to 27.20%. In September 1988, before a severe adjustment program, prices increased by 114.12%, the highest level during that year. From that period on, inflation increased dramatically until it reached hyperinflationary levels. During 1989 the inflation rate was increasing but less volatile than the previous year. By 1990 the annual inflation rate reached a record of 7,650 and it was extremely volatile: it ranged from 397% in August to 23.70% in December.

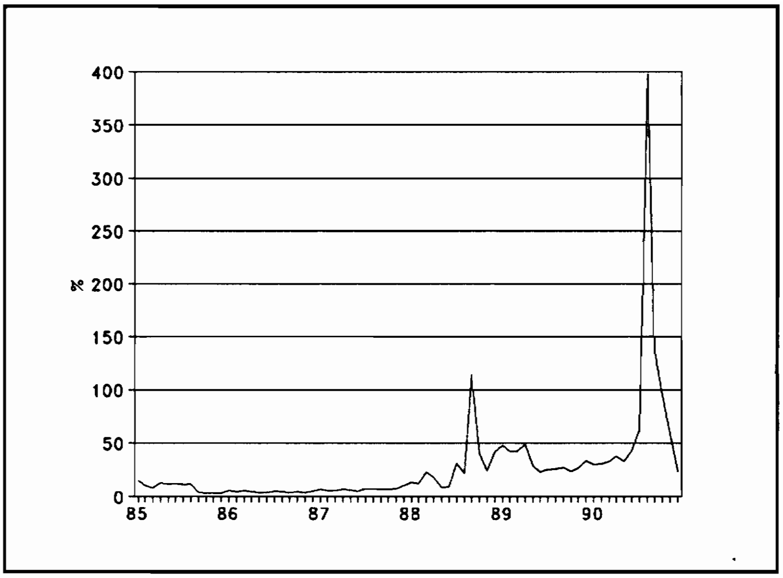

Figure 4.3 Monthly Inflation Rate 1985-1990.

Inflation rate and relative price variability for the period of 1979:12-1988:07 is plotted in figures 4.4 and 4.5. Relative price variability is measured as the observed variance of the changes of individual prices around the mean. Some correlation of the relative price variability and inflation is apparent. In particular, it can be seen that relative price variability exhibits a higher mean and greater dispersion after 1985, when inflation started accelerating.

Even though there is a sharp change on the average inflation during the half of the second year of the Garcia administration, these months were included in the sample to test the hypothesis that during periods of high and variable inflation, relative price change variability increases.

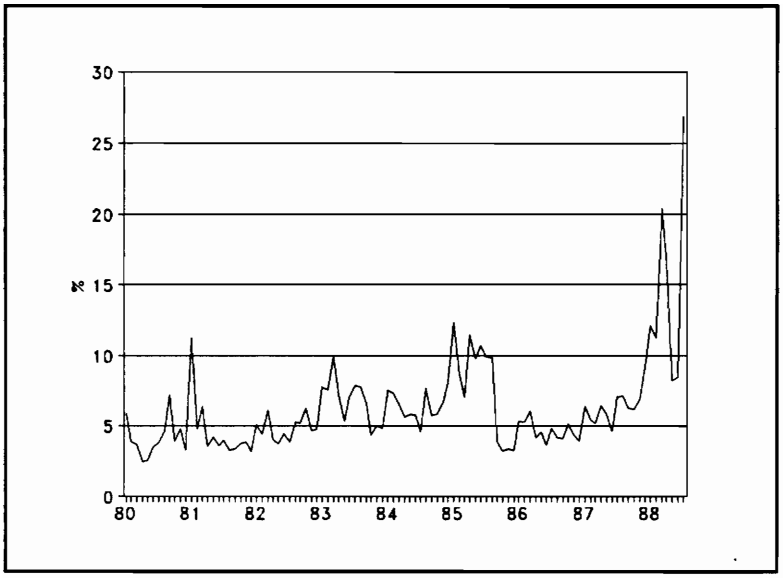

Figure 4.4 Monthly Inflation 1980:01 - 1988:07

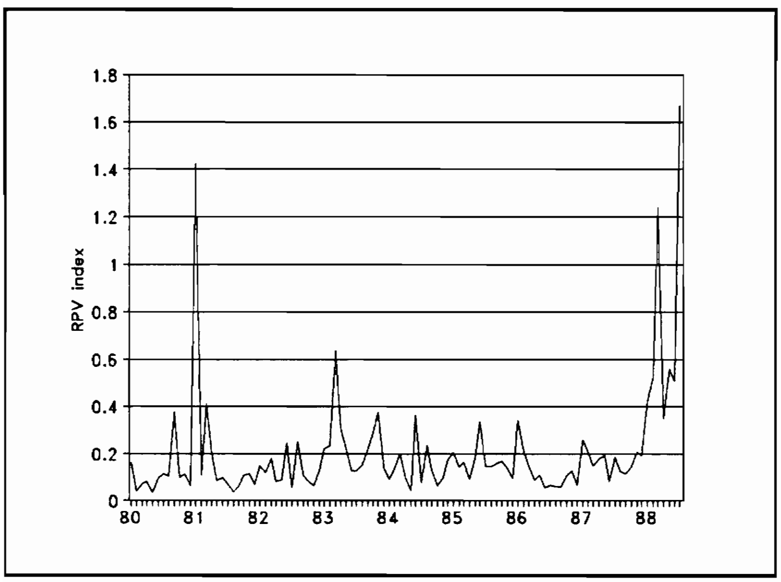

Figure 4.5 Relative Price Variability 1980:01 - 1988:07

Table 4.2 presents a summary of the average monthly inflation rate and the structure of relative price changes during the period 1976-1990. As can be seen, the volatility of inflation was high not only during the last years, but when price controls where applied more intensively, i.e. years 1976 and 1985-1990. The instability of the inflation rate was caused by the government's constantly changing objectives for the prices it controlled during the period 1979-1990.

Table 3.5 Inflation and Relative Price Change Variability 1980-1990

year	Average Monthly Inflation	Volatility[a] of Inflation	Relative Price Changes Variability[b]
1976	3.2	114.2	n.a.
1977	2.4	69.1	n.a
1978	4.7	62.4	n.a.
1979	4.4	32.4	n.a.
1980	4.0	36.3	209.5
1981	4.7	48.9	90.9
1982	4.7	21.1	91.3
1983	7.0	24.2	279.1
1984	6.4	17.5	177.0
1985	8.3	48.0	604.7
1986	4.2	14.6	664.6
1987	6.6	18.1	1,071.1
1988	29.7	93.2	132,651.3
1989	32.6	28.8	4,266,632.7
1990	81.9	122.4	7,375,365.4

Source: Own calculations based on consumer price data from Webb and Fernadez Baca (1990). See Appendix.

a. The coefficient of variability (standard deviation divided by the mean) multiplied by 100.

b. Given by the formula $sum(Dp_i - DP)^2$, where Dp_i is the price change of commodity i and DP is the general price change. The summation covers 8 groups of the consumption basket used to generate the CPI.

In the absence of some generalized indexation scheme the relative price structure also endured continuous fluctuations that did not necessarily reflected changes in relative availability of goods. Increasing relative price variability resulted from changes in government's policy for the prices it controlled and uncertainty regarding future inflation. In the next section the relation between relative price variability and inflation uncertainty will be tested empirically.

4.4 Econometric Modelling

This section presents a description of the econometric techniques used in the analysis. Section 4.4.1 presents a brief summary of the assumptions underlying the linear regression model which are tested in the subsequent sections. The stochastic process called autoregressive conditional heteroscedastic (ARCH) is described in Section 4.4.2. The regression model following an ARCH process is also presented in this section.

4.4.1 The linear regression model[3]

Let $Z_t = (y_t, X_t)$, be a vector stochastic process representing the vector of random variables giving rise to the observed data chosen to model. The variable whose behaviour is going to be explained is y_t. In

[3] This section is based on Spanos (1986).

the specification of the linear regression model, the stochastic process Z_t is assumed to be normal, independent and identically distributed (NIID).

The joint distribution $D(Z_1 \ldots Z_T, \theta)$ is reduced to define the statistical generating mechanism (GM) of the linear regression model using the general form:

$$y_t = \mu_t + u_t \tag{4.1}$$

where

$$\mu_t = E(y_t/X_t = x_t) \tag{4.2}$$

is the systematic component, and:

$$u_t = y_t - E(y_t/X_t = x_t) \tag{4.3}$$

is the non-systematic component.

In view of the normality of Z_t it can be infered that the systematic component is linear in x_t and that the conditional variance is free of x_t, i.e. is homoskedastic:

$$\mu_t = E(y_t/X_t = x_t) = \beta_0 + \beta' x_t \tag{4.4}$$

$$Var(u_t/X_t=x_t) = Var(y_t/X_t=x_t) = \sigma^2 \tag{4.5}$$

In addition, the parameters of interest, β_0, $\boldsymbol{\beta}$ and σ_2 are time invariant due to the identically distributed assumption related to Z_t.

Misspecification testing refers to analyzing the statistical adequacy of the model. The null hypothesis is defined by the assumptions discussed above, N.I.I.D. Departures from these assumptions will imply that the model chosen is not statistically adequate and consequently inference may be misleading.

Normality assumption can be evaluated using the skewness-kurtosis test by examining the scaled third and fourth conditional moments, α_3 and α^4. Under normality, the test statistic T(y):

$$T(y) = [(T/6)\alpha_3^2 + (T/24)(\alpha_4 - 4)^2 \qquad (4.6)$$

has a Chi-square distribution with two degrees of freedom.

Let the sampling model of interest be:

$$y_t = \beta' x_t + u_t \qquad (4.7)$$

A test of **independence** can be constructed based on the significance of the parameters $\alpha = (\alpha_1 ... \alpha_m)$ and $\beta = (\beta_1 ..... \beta_m)$ from the following equation:

$$y_t = \beta_0' x_t + \sum_{i=1}^{m} (\alpha_i y_{t-i} + \beta_i' x_{t-i}) + u_t \qquad (4.8)$$

An F-type test procedure is suggested:

$$\tau(y) = \frac{RRSS-URSS}{URSS} \left(\frac{T - k(m + 1)}{mk}\right) \qquad (4.9)$$

where RRSS and URSS stand for the residual sum of squares of equations 4.7 (restricted equation) and 4.8 (unrestricted equation). In small samples $\tau(y)$ has an F(mk, T-k(m+1)) distribution.

In order to test **linearity**, an F-type test can also be used. In this case the unrestricted equation has the form:

$$y_t = \beta_0' x_t + \gamma_2' \psi_{2t} + \gamma_3' \psi_{3t} + u_t \qquad (4.10)$$

where ψ_{2t} includes the second-order terms

$$x_{it}x_{jt}, \qquad i \geq j, \qquad i,j = 2,3....k \qquad (4.11)$$

and ψ_{3t} includes the third-order terms

$$x_{it}x_{jt}x_{lt}, \qquad i \geq j \geq l, \qquad i,j,l = 2,3....,k \qquad (4.12)$$

Then, linearity can be tested in the form of:

$H_0: \gamma_2 = 0$ and $\gamma_3 = 0$, $\qquad H_1: \gamma_2 \neq 0$ and $\gamma_3 \neq 0$

Finally, testing departure from **homoskedasticity** can be done using the White (1980) test. This test is based on the R^2 of the auxiliary equation:

$$u_t^2 = \alpha_0 + \alpha_1\psi_{it} + \alpha_2\psi_{2t} + ...+ \alpha_{mt}\psi_{mt} \qquad (4.14)$$

where:

$$\psi_{lt} = x_{it}x_{jt}, \qquad i \geq j, \quad i,j = 2,3...k, \qquad l = 1,2.....m$$

Under the assumption of homoskedasticity,

$$TR^2 \sim \chi^2(m) \qquad (4.14)$$

where T is the sample size.

In section 4.5 the relationship between relative price variability and inflation is analyzed within the context of the linear regression model. The statistical adequacy model is examined by using the tests discussed above.

4.4.2 Autoregresive Conditional Heteroscedasticity Processes[4]

A major component of the welfare loss associated with inflation is the unpredictability of future changes in prices. Modelling price uncertainty has been a difficult task, because the econometric tools available rely on the assumption of constant conditional variance.

If a random variable y_t is drawn from the conditional density function $f(y_t|y_{t-1})$, the forecast of today's value based upon past information, is $E(y_t|y_{t-1})$. The variance of this one-period forecast is given by $V(y_t|y_{t-1})$, which under the linear regression model does not depend on past information, i.e., $V(y_t) = \sigma^2$. Engle (1982) developed an econometric model in which both the conditional mean and variance jointly evolve over time.

Engle (1982) introduces a class of stochastic processes called autoregressive conditional heteroscedastic (ARCH), which are mean zero, serially uncorrelated with nonconstant conditional variances, but constant unconditional variances. For such processes, the recent past gives information about the forecast variance.

For economic agents what is relevant is the conditional densities of inflation given all past information. From these densities, conditional moments can be defined, and in general, they will depend upon the

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[4] This section is based on Engle (1982), "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation" and Engle (1983), "Estimates of the Variance of U.S. Inflation Based upon the ARCH Model".

conditioning information set. The ARCH model--which is described in the next sub-section--allows these moments to be defined.

4.4.2.a The ARCH Regression Model

The ARCH model allows the variance to change over time. The variance in one period is allowed to depend upon variables known from previous periods including the disturbances. The model recognizes the difference between the conditional and unconditional variance; the conditional variance may depend upon random variables in the conditioning set, while unconditional variance is constant.

The model is formulated in terms of an information set ψ_t that includes all information available throughout time *t*. Letting y_t be the dependent variable, x'_t the vector of explanatory variables included in ψ_{t-1}, the *pth* order linear ARCH regression model can be formulated as:

$$y_t|\psi_{t-1} \sim N(x_t\beta, h_t) \tag{4.15}$$

$$h_t = \alpha_0 + \alpha_1\epsilon^2_{t-1} + \alpha_2\epsilon^2_{t-2} + \ldots\ldots + \alpha_p\epsilon^2_{t-p} \tag{4.16}$$

$$\epsilon_t = y_t - x_t\beta \tag{4.17}$$

It is assumed that the mean of y_t is given as $x_t\beta$, a linear combination of lagged endogenous and exogenous variables included in the information set ψ_{t-1}, with β a vector of unknown parameters. The conditional variance, h_t, depends on past disturbances.

Although the conditional distribution of y_t is normal, the *y's* are not jointly nor marginally normal. The jointly density is given as the product of all the conditional densities and the log likelihood function is:

$$L = -\frac{T}{2}\log(2\pi) - \sum_{t=1}^{T}\log(h_t) - \frac{1}{2}\sum_{t=1}^{T}\frac{\epsilon_t^2}{h_t} \tag{4.18}$$

Procedures for maximizing this likelihood function are derived in Engle (1982). There are two sets of parameters, α and β, that are proven to be asymptotically independent and, therefore, the likelihood function can be maximized separately for each.

There are restrictions on the admissible coefficients on α. If any of these coefficients is negative, then a large residual could drive the conditional variance negative. Thus, the alpha parameters are restricted to be nonegative. Second, if the alphas are too large, then the process will eventually have an infinite variance. To resolve this second restriction, Engle suggests to restrict them to lie in the stable region. The condition is that the difference equation:

$$z_t = \alpha_1 z_{t-1} + \ldots . + \alpha_p z_{t-p} \tag{4.19}$$

must be stable. A necessary condition for this is that the sum of the alphas be less than unity.

Engle (1982,1983) estimates the variance of inflation for the United Kingdom and United States using the ARCH model. Assuming that agents discount past residuals, a linearly declining set of weighs was formulated to give the model:

$$h_t = \alpha_0 + \alpha_1 \left(\frac{\sum_{j=1}^{p} (p - j)\epsilon_{t-j}^2}{\sum_{j=1}^{p} j} \right) \tag{4.20}$$

where p is the lag order of the ARCH process. Engle points out that the variance models was assumed to be a two-parameter model (α_0 and α_1), primarily because it seemed that nonnegativity and stationarity constraints on the α's would be hard to satisfy in the more general case.

In order to test for ARCH processes, Engle (1982) suggests to use the LaGrange Multiplier test procedure. Under the null hypothesis, $\alpha_1 = \alpha_2 = \ldots \alpha_p = 0$. The test procedure is to run the OLS regression and save the residuals. Regress the squared residuals on a constant and p lags and test TR^2 as a $\chi_p{}^2$. Where T (sample size) and R^2 are obtained from the OLS regression with the squared residuals.

4.5 Empirical Analysis

This section presents the results from the empirical analysis. In section 4.5.1 the stationarity properties of the series are evaluated based on Dickey-Fuller unit root tests. The model used to forecast inflation and the results of testing the effects of expected and unexpected inflation on observed relative price change variability are summarized in Section 4.5.2. The results from modelling the relationship between the conditional relative price variability and the conditional variance of inflation are presented in section 4.5.3.

4.5.1 Mean Stationarity on the Series

For an arbitrary stochastic process the distribution function $F(Y_t;\theta_t)$ depends on t with the parameters θ_t being a function of t as well. This implies that the stochastic process is time-heterogeneous in general. However, for real phenomena there is only one observation for each t, which complicates the empirical modelling. For this reason it is important to consider a class of stationary processes which exhibit considerable time-homogeneity and can be used to model phenomena approaching their **equilibrium steady-state**, but continuously undergoing random fluctuations. This is the class of stationary stochastic processes.

The Dickey-Fuller likelihood ratio test for autoregressive time series with a unit root is used to test if the series are stationary stochastic processes. Let the time series Y_t satisfy $Y_t = \alpha + \beta t + \rho Y_{t-1} + \epsilon_t$, where Y_t is fixed and the residuals are normal independent $(0,\sigma^2)$ random variables. The test, ϕ_3, consists of evaluating the hypothesis H_0: $(\alpha,\beta,\rho) = (\alpha,0,1)$, i.e., the time series is a random walk with drift α. The estimate statistic ϕ_3 is the common regression "F test" one could construct for this hypothesis. The resulting estimated ϕ_3 is compared with empirical distribution of ϕ_3, which is simulated by Dickey and Fuller (1981). Table 4.3 summarizes the results from this test.

The specification of the empirical models of interest requires first the identification of an appropriate data transformation to achieve mean stationarity. Dickey-Fuller tests were used to test for the presence of unit roots in the series of domestic CPI, relative price variability, real exchange rate and U.S. CPI. As can be seen, for the CPI and relative price variability series the hypothesis that the series are stationary stochastic processes is not rejected.

Since the Peruvian economy is highly dependent on the external sector, two variables that may be accounting for external influence on the price change variability were also included in the empirical models. These two variables are the real exchange rate and U.S. relative price variability, as in Blejer and Leiderman (1981) and Blejer (1982) studies for Mexico and Argentina, respectively.

The real exchange rate series is constructed by dividing the relevant exchange rate by Peru's consumer price index and multiplying it by the U.S. consumer price index. It would have been desirable to have a series of multilateral real exchange rates, constructed by weighing the bilateral real exchange rates of the Peruvian major trading partners. But since the U.S. is one of the most important trading partners, this is an appropriate proxy for measuring external shocks. For the same reason, U.S. relative price change variability may also be having an effect on Peruvian RPV. U.S. relative price change variability is constructed using a eight commodity breakdown[5]. The results also suggest that the hypothesis of a unit root for the series of real exchange rate and U.S. CPI is accepted.

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[5] The commodity groups included were: food, housing, transportation, medical care, entertainment, other goods and services, personal care and personal and educational expenses. Data was obtained from Citibase Citicorp Economic Database.

Summarizing, the results from the Dickey and Fuller tests suggest that first differences rather than time trends should be used for all variables to remove nonstationary elements. For these purpose domestic inflation, relative price change variability, real exchange rate changes and U.S. inflation will be expressed as first log differences of the levels of the series.

Table 4.3: Dickey-Fuller Univariate Unit Root Tests

	Consumer Price Index	Domestic Relative Price Variability	Real Exchange Rate	U.S. Consumer Price Index	10% Critical Value
A. Full Sample, 1979:12 - 1990:03					
Unit Root					
ϕ_3	3.07	2.29	4.10	4.86	5.47
Lag length	4	7	3	10	
B. Pre-Hyperinflation Sample, 1979:12 - 1988:07					
Unit Root					
ϕ_3	3.45	5.09	3.07	5.13	5.47
Lag length	1	1	3	12	

4.5.2 Observed Relative Price Variability and Inflation

As a first step, the relation between relative price variability and inflation will be studied using the standard method. Relative price variability will be measured as the variance of the observed changes in relative prices around the mean.

As discussed previously, one source of relative price variability may be "unexpected" changes in the price level. During periods of rapid and volatile inflation rates, a second source of relative price change variability may arise from different speeds of adjustment among sectors in the economy. Under this latter consideration, "expected" inflation will also be positively related to relative price variability.

4.5.2.a Modelling Expected and Unexpected Inflation

To obtain a proxy for expected and unexpected inflation an autoregressive inflation model consisting of lagged values of observed inflation was specified. A *pth* order autorregresive process was assumed to estimate expected and unexpected inflation. The statistical model is:

$$DP_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i DP_{t-i} + u_t \qquad (4.21)$$

where DP_t is the inflation rate. Initially, equation 4.21 was estimated for the full sample and the statistically adequacy of the model is strongly rejected. This supports the decision to reduce the sample size to the period 1979:12 - 1988:07, before the Peruvian economy started to show signs of hyperinflation. However at the end of the period, inflation rates rise rapidly. To account for this change in the pattern of inflation a dummy variable is included. This dummy variable reflects a

Table 4.4 Inflation Forecast Model

Dependent Variable	Constant	DP_{t-1}	DP_{t-2}	DP_{t-3}	DP_{t-4}	DP_{t-5}	D_t	R^2
DP_t	1.65**	0.35**	0.08	-0.15*	0.02	0.38**	0.18**	0.70
	(3.14)	(5.11)	(1.15)	(-2.08)	(0.34)	(5.04)	(3.76)	

Notes:
1. *t*- values are in parenthesis. ** and * indicate significance at five and ten percent respectively.
2. DP_t is the inflation rate.

Table 4.5 Misspecification Tests

1. Independence Test:

Dep. Variable	Constant	DP^e_{t-1}	$Resids_{t-1}$	$Resids_{t-2}$	$Resids_{t-3}$	$Resids_{t-4}$	D_t	Chi-Sq(4)
$Resids_t$	0.28	-0.04	0.04	0.10	0.18	0.12	0.18**	6.76
	(0.82)	(-0.90)	(0.37)	(1.01)	(1.68)	(1.16)	(3.76)	

2. Linearity Test:

Dep. Variable	Constant	DP^e_t	$(DP^e_t)^2$	F(1,100)
$Resids_t$	-0.57	0.13	-0.004	1.36
	(-0.80)	(0.94)	(-1.17)	

3. Homoskedasticity Test:

Dep. Variable	Constant	$(DP^e_t)^2$	$(DP^e_t)^3$	Chi-Sq(2)	F(2,100)
$Resids^2_t$	2.60	0.03	-0.0005	4.83	2.46
	(2.38)	(1.29)	(-0.91)		

4. Normality Test:

$$\theta(y) = T/6*(\text{skewness})^2 + T/24*(\text{kurtosis}-3)^2$$
$$\text{Chi-Squared}(2) = 99/6*(0.51125)^2 + 99/24*(2.26337 - 3)^2 = 6.55$$

Notes:
1. Values in parenthesis under the coefficients estimates are *t*- values.
2. The critical value for a Chi-Square with 4 degrees of freedom at 5% and 2% of significance is 5.991 and 7.824, respectively.
3. DP^e_t is the estimated value of inflation rate obtained from the AR(5) model.

change on the slope of inflation due to a suspension of price controls, 1987:10–1988:07.

The modelling strategy followed the general-to-specific specification search procedure. First, an overparameterised model was estimated and the statistical adequacy of the model was tested. Subject to these tests being passed, the model was reduced by progressive elimination of the least significant lags. The final model selected is an AR(5) process and the results are shown in Table 4.4. Table 4.5 presents the results of testing the statistical adequacy of the model. As can be seen, the homoskedasticity, linearity and independence assumptions were not rejected. On the other hand, the normality assumption is rejected at the 5% level but accepted at the 2% level.

4.5.2.b Observed Relative Price Variability and its Determinants

After obtaining the inflation forecast model, the next step is to examine empirically the relationship between relative price variability and expected and unexpected inflation. Observed relative price variability is measured as the weighted sum of squared deviations around the mean.

$$\begin{aligned} RPV_t &= \sum_{i=1}^{n} wi[(\ln(p_{i,t}) - \ln(P_t)) - (\ln(p_{i,t-1}) - \ln(P_{t-1}))]^2 \\ &= \sum_{i=1}^{n} wi(Dp_{i,t} - DP_t)^2 \end{aligned} \qquad (4.22)$$

Equation 4.23 is proposed as the statistical model that will represent the relative price variability time series:

$$RPV_t = \alpha_0 + \sum_{i=0}^{m} (\alpha_i DP^e_{t-i} + \beta_i DP^u_{t-i} + \delta_i RER_{t-i} + \theta_i RPV^*_t) + \sum_{i=1}^{n} \gamma_i RPV_{t-i} + u_t \qquad (4.23)$$

where RPV_t is relative price variability, DPe_t is expected inflation and DPu_t is unexpected inflation. The two last series are obtained from the fitted values and residuals from equation 4.21, respectively. The bilateral exchange rate is RER_t and RPV^*_t is U.S. observed relative price variability.

The regression results are reported in Table 4.6. In these models, relative price variability is assumed to depend only on domestic inflation and its own lagged values. The regression results suggest that unexpected inflation has a significant effect on relative price variability. While expected inflation is not found significant, the effect of unexpected inflation lasts only for two periods. On the other hand, expected inflation is not found significant. Table 4.7 summarizes the statistical adequacy tests for the second equation from table 4.6, which excluded lagged expected inflation. The second specification seems to be statistical adequate.

Table 4.8 presents the results of the full model that includes U.S. relative price variability and the real exchange rate. The foreign price variability is not significant but the real exchange rate turn out to be marginally significant. The estimate parameter of the real exchange rate is negative. If U.S. inflation is increasing relatively less than the domestic inflation, then the real exchange rate decreases and relative price variability increases.

It is important to notice that the coefficient of real exchange rate is larger in absolute value than the one of unexpected inflation. This result suggests that during the period of analysis the observed relative price movements were more sensitive to changes in the real exchange rate in the Peruvian economy.

The results from the regressions shown in Table 4.8 also suggest that the empirical model relating relative price variability to inflation is stable. Adding more explanatory variables did not change the sign and magnitude of the estimate parameters of expected and unexpected inflation. Unexpected inflation remains significant and expected inflation is not significant.

Summarizing, empirical evidence is found supporting the hypothesis that unexpected inflation increased relative price change variability in the Peruvian economy for the period 1979:12 - 1988:07 is found. Contrary to what some other empirical studies have found, the Peruvian data does not show that expected inflation affects relative price change variability. This analysis does not support the hypothesis of different speeds of adjustment among sectors in the economy in response to anticipated inflation.

Table 4.6 Relative Price Variability and Inflation. An imperfect Information Approach
Dependent Variable: Observed Relative Price Variability (RPV_t)

Constant	DP^u_t	DP^u_{t-1}	DP^u_{t-2}	DP^e_t	DP^e_{t-1}	DP^e_{t-2}	RPV_{t-1}	RPV_{t-2}	D_t	R^2
0.111**	0.027**	0.002	0.021**	0.003	-0.016	0.012	0.168**	0.072	1.27**	0.747
(2.46)	(3.77)	(0.02)	(2.50)	(0.35)	(-1.54)	(1.38)	(2.23)	(1.31)	(10.8)	
0.107**	0.025**	0.003	0.016**	0.001			0.101	0.095*	1.297**	0.738
(2.44)	(3.58)	(0.40)	(2.02)	(0.14)			(1.59)	(1.86)	(11.89)	

Notes:

1. *t*- values are in parenthesis. ** and * indicate significance at five and ten percent respectively.
2. DP^e_t is the expected inflation rate calculated as the fitted values from a second-order autoregressive process with dummy variables. DP^u_t is the unexpected rate of inflation and equals DP_t - DP^e_t

Table 4.7 Misspecification Tests

1. Independence Assumption Test

Dep. Var.	Constant	DP^u_t	DP^u_{t-1}	DP^u_{t-2}	DP^e_t	RPV_{t-1}	RPV_{t-2}	D_t	Res_{t-1}	Res_{t-2}	Res_{t-3}	Res_{t-4}	Chi - Sqr(4)
$Resids_t$	0.016	0.003	0.007	-0.002	-0.005	-0.037	0.127	0.059	0.155	-0.231	-0.028	-0.227	9.83
	(0.38)	(0.04)	(0.89)	(-0.62)	(-0.62)	(-0.51)	(1.81)	(0.53)	(1.19)	(-1.73)	(-0.24)	(-2.01)	

2. Linearity Assumption Test

Dep. Var.	Constant	DP^u_t	DP^u_{t-1}	DP^u_{t-2}	DP^e_t	RPV_{t-1}	RPV_{t-2}	D_t	$(RPV^e_t)^2$	F(1,82)
Res_t	-0.05	-0.04	-0.03	-0.026	-0.003	-0.016	-0.016	-10.32	5.200	3.08
	(-0.99)	(-1.68)	(-0.04)	(-1.56)	(-0.35)	(-1.53)	(-1.46)	(-1.75)	(1.75)	

3. Homoskedasticity Assumption Test

Dep. Var.	Constant	$(RPV_t)^2$	$(RPV_{t-1})^2$	$(RPV_{t-2})^2$	F(4,83)
$(Res_t)^2$	0.006	0.015	0.002	0.005	1.14
	(2.80)	(1.60)	(0.17)	(0.61)	

4. Normality Test:

$$\theta(y) = T/6^*(\text{skewness})^2 + T/24^*(\text{kurtosis}-3)^2$$
$$\text{Chi-Squared}(2) = 79/6^*(0.48)^2 + 79/24^*(3.45 - 3)^2$$
$$= 3.70$$

Notes:
1. The critical values for a Chi-Square with 4 degrees of freedom at 5% of significance is 5.991.
2. The critical value for a F(1,82) variable is 3.96 at five percent of significance and for a F(4,83), 2.48.
3. The critical value for a Chi-Square with 2 degrees of freedom at 5% of significance is 5.991.

Table 4.8 Relative Price Variability, Inflation and Foreign Shocks
Dependent Variable: Observed Relative Price Change Variability (RPV_t)

Constant	DP^u_t	DP^u_{t-1}	DP^u_{t-2}	DP^e_t	RPV^*_t	RPV^*_{t-1}	RPV^*_{t-2}	RER_t	RER_{t-1}	RER_{t-2}	RPV_{t-1}	RPV_{t-2}	D_t
0.150**	0.019**	0.007	0.017*	0.001	-1.232	-2.527	2.925	-0.999*	0.075	0.278	0.147*	0.189**	1.22**
(2.46)	(2.30)	(0.70)	(1.76)	(0.14)	(-0.50)	(-1.01)	(1.16)	(-1.69)	(0.11)	(0.43)	(1.72)	(2.38)	(9.75)
0.127**	0.022**	0.101	0.014*	-0.002	-0.367	-1.747	-0.216				0.092	0.168**	1.32**
(2.61)	(3.07)	(1.18)	(1.74)	(-0.31)	(0.16)	(-0.75)	(-1.49)				(1.42)	(2.71)	(12.8)
0.109**	0.020**	0.123	0.013*	-0.002				-0.773	0.748	-0.184*	0.128*	0.151	1.270**
(2.19)	(2.68)	(1.37)	(1.69)	(-0.17)				(-1.61)	(1.41)	(-1.78)	(1.89)	(2.61)	(12.97)

Note:
1. *t*-values are in parenthesis. ** and * indicate significance at five and ten percent respectively.

4.5.3 Conditional Relative price Variability

As discussed in Section 3.2, the use of observed relative price variability neglects the distinction between expected and unexpected relative price changes. It is too restrictive to assume that all relative price changes take the private sector by surprise. Some of these movements in prices may be responses to anticipated changes in supply or demand. Using conditional relative price variability will help to isolate expected from unexpected relative price changes.

Using an ARCH regression model, measures of conditional relative price variability and conditional variances of domestic inflation, real exchange rate and U.S. price variance were constructed. The conditional relative price variance (CRPV) is defined as the average variance of local output price forecast errors across markets:

$$CRPV_t = \sum_{i=1}^{n} w_i E_{t-1}(\epsilon_{i,t})^2 \tag{4.24}$$

where the relative price forecast error is defined as :

$$\epsilon_{i,t} = [DP_{i,t} - DP_t] - E_{t-1}[DP_{i,t} - DP_t] \tag{4.25}$$

The 32 commodity groups used to construct the CPI in the previous section was aggregated into 8 broad groups in order to have a more manageable number of prices to model. The forecast models for the 8 relative price series and the aggregate variables are initially assumed to follow an AR(p) process.

The estimated residuals of the forecast models are then used to test whether the series followed an autoregressive conditional heteroscedastic process. To evaluate the null hypothesis of constant variance, Engle's (1982) LaGrange multiplier test is used. Table 4.9 summarizes the results of the test. The ARCH factors indicated in Table 4.9 are the significant lags of the squared residual of the forecast model regressions. The computed values of χ^2 reject the null hypothesis of constant variance in all the cases.

Table 4.9 ARCH Test Results

Variable	Chi-Sq.	Factors	Variable	Chi-Sq.	Factors
1. U.S. Inflation	6.02**	1	7. Transportation and Communication	14.40**	4
2. Real Exchange Rate	21.23**	8	8. Healthcare	14.56**	2
3. Domestic Inflation	9.52**	3	9. Education	26.58**	6
4. Food and Beverages	7.02**	2	10. Food Outside Home	32.19**	4
5. Clothing and Shoewear	9.91**	1	11. Other	31.43**	8
6. Housing	12.44**	4			

Notes:
1. Chi-Sq is the test statistic of Engle's LaGrange multiplier test for ARCH residuals. The statistic follows a chi-squared distribution with degrees of freedom equal to the number of factors.
2. ** indicate significance at five percent level.

Using the ARCH factors identified in the test the forecast models for each variable are reestimated together with the parameters of its conditional variance process. Engle's (1982) maximum likelihood estimator is used to obtain efficient estimates of the parameters of both parts of the model, conditional mean and conditional variance. With these estimates, the empirical proxies of the conditional variance processes,

$\sigma^2_{z,t}$, are constructed for each variable z, i.e. 8 relative prices, domestic inflation, real exchange rate and U.S. inflation. .

An empirical index of conditional relative price variability can be obtained by aggregating the conditional variance processes of the 8 relative price series. This index incorporates the fact that the conditional variances depend empirically on their own past. For the purpose of this study, what is relevant is the component of the variances which cannot be explained by their own past, i.e a measure of uncertainty. What is needed is the conditional variances of the maximum likelihood residuals of the forecast models: $E_{t-1}[\epsilon^2_{zt}/\sigma^2_{zt}]$. By construction, the conditional variances of the maximum likelihood residuals do not have an autoregressive structure, because all information about their past has been incorporated in their estimation.

To obtain a proxy for the component of CRPV that is unexplained by its own past the squared maximum likelihood residuals for the 8 relative price series are summed up:

$$CRPV_t = \sum_{i=1}^{8} \omega_i \left(\frac{\epsilon^2_{i,t}}{\sigma^2_{i,t}} \right) \tag{4.26}$$

This index, $CRPV_t$, is the dependent variable used to model the relation between relative price variance and inflation. In addition, an estimate of the variance of U.S. inflation and of the variance of the real exchange rate is also included.

The statistical model proposed takes the form:

$$CRPV_t = \alpha_0 + \sum_{i=0}^{m} (\alpha_i \sigma^2_{P,t} + \beta_i \sigma^2_{X,t} + \gamma_i \sigma^2_{US,t}) + \sum_{i=1}^{n} \delta_i CRPV_{t-i} + u_t \qquad (4.27)$$

where:

σ_P^2 = conditional variance of domestic inflation rate,

σ_X^2 = conditional variance of the real exchange rate,

σ_{US}^2 = conditional variance of U.S. inflation rate.

Equation 4.27 suggests that the conditional relative price change variability is a function of the conditional variance of inflation and of other nominal and real shocks. The predicted sign of the estimate parameters of the independent variables is positive. This specification is different from equation 4.21 because $CRPV_t$ incorporates only relative price deviations from the mean that are not explained by their own past, whereas in equation 4.21 the dependent variable is the observed relative price change variability.

The regression results are reported in Table 4.10. Initially four lags of all variables were included, and as in section 4.5.2 the general-to-particular specification search approach procedure was used. Two dummies that reflect policy changes that affected the variability of relative price changes were included. These dummy variables are for the months 1985:09 and 1988:03. In September 1985 the Garcia administration started its price control program. In March 1988, a "Selective Policy

Package" was applied, which included a sharp nominal increase in controlled prices of food-stuffs and fuels and in the prices charged by the public sector and the announcement that controlled prices would remain fixed for four months.

As shown in Table 4.10, after eliminating nonsignificant lags from the equation, all significant parameters estimates are positive, as was predicted by the theoretical model. Price uncertainty, measured as the conditional variance of domestic inflation, has a strong effect on relative price variability and it lasts for four periods. The conditional real exchange rate variance is also significant. In addition, U.S. conditional inflation variance is not found significant.

The regressions results for this second model indicate that the lag structure of price uncertainty and the dependent variable is larger than for the first model. These results seem more plausible since the data used is on a monthly basis and some time adjustment is expected.

Finally, the statistical adequacy of the regression reported on Table 4.10 is summarized on Table 4.11. The assumptions of independence, homoskedasticity and linearity are not rejected, whereas normality is marginally rejected.

Table 4.10 Conditional Relative Price Variability and Inflation Uncertainty
Dependent Variable: Conditional Relative Price Variability ($CRPV_t$)

Constant	$CRPV_{t-1}$	$CRPV_{t-2}$	$CRPV_{t-3}$	$CRPV_{t-4}$	σp_t	σp_{t-1}	σp_{t-2}	σp_{t-3}	σp_{t-4}	σp_{t-5}	σx_{t-1}	D1	D2	R^2
0.04 (0.25)	-0.03 (0.39)	-0.01 (0.19)	-0.11 (-0.17)	0.36 (5.79**)	0.45 (5.45**)	0.03 (0.37)	0.07 (0.93)	-0.02 (-0.28)	-0.17 (-2.88**)	0.13 (2.47**)	0.19 (1.83*)	5.51 (7.09**)	9.32 (6.34**)	0.82

Notes:
1. *t*- values are in parenthesis. ** and * indicate significance at five and ten percent respectively.
2. σp_t is the variance of inflation calculated from an ARCH model and σx_t is the variance of the real exchange rate calculated from an ARCH model.

Table 4.11 Misspecification Tests

1. Independence Assumption Test

Dep. Var.	Constant	$CRPV^e_t$	$Resids_{t-1}$	$Resids_{t-2}$	$Resids_{t-3}$	$Resids_{t-4}$	Chi(4)
$Resids_t$	-0.09	0.06	0.13	-0.10	-0.22	-0.16	7.99
	(-1.03)	(1.12)	(1.01)	(-0.80)	(-1.87)	(-1.37)	

2. Linearity Assumption Test

Dep. Var.	Constant	$CRPV^e_t$	$(CRPV^e_{t-1})^2$	F(1,79)
$Resids_t$	0.19	-0.34	0.04	6.74
	(1.65)	(-2.43)	(2.59)	

3. Homoskedasticity Assumption Test

Dep. Var.	Constant	$(CRPV_{t-1})^2$	$(CRPV_{t-2})^2$	$(CRPV_{t-3})^2$	F(3,78)
$(Resids_t)^2$	0.53	-0.01	-0.01	-0.004	0.29
	(4.00)	(-0.57)	(-0.56)	(-0.54)	

4. Normality Test:

$$\theta(y) = T/6*(skewness)^2 + T/24*(kurtosis-3)^2$$
$$Chi\text{-}Squared(2) = 82/6*(1.001)^2 + 82/24*(3.36 - 3)^2$$
$$= 14.14$$

Notes:
1. $CRPV^e_t$ is the estimated conditional relative price variability.
2. The critical value for a Chi-Square with 4 degrees of freedom at 5% of significance is 9.488 and with 2 degrees of freedom is 5.99.
3. The critical values for a F(1,82) variable are 3.96 and 6.84 at five and one percent of significance respectively. For a F(3,78) are 2.72 and 4.04.

4.6 Summary and Conclusions

This Chapter has presented an empirical analysis of the impact of the different components of inflation and other aggregate variables on relative price variability. The empirical analysis was carried out with monthly data on the consumer price index from Peru for the period 1979:12-1988:07.

Two different models were estimated. The first model followed the traditional measure of relative price variability. This measure is the observed relative price variability and is constructed as weighted relative price change deviations from the mean. The explanatory variables used were expected and unexpected inflation, both obtain from an AR(5) model of inflation and the real exchange rate and U.S. relative price variability. In addition a time lag of the dependent variable was used in the regressions.

The main results of the first model can be summarized as follows. The estimated parameter of unexpected inflation is positive, confirming the hypothesis that unanticipated changes in the price level may cause relative price change variability. The coefficient of real exchange rate show the expected negative sign and is larger in absolute value than the coefficient of unexpected inflation. Expected inflation was not found to be significant.

For the second model, using the ARCH approach, the conditional variances of the 8 relative prices were estimated and used to construct an index of conditional relative price variability. Similarly, conditional variances of real exchange rate, domestic inflation and U.S. inflation were estimated.

The empirical results indicate that there is a significant effect of the conditional variances of domestic inflation and of the real exchange rate on conditional relative price variance. The coefficients of the conditional variance inflation and of the real exchange rate variability are positive and significant. The conditional variance of U.S. inflation was not found significant.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Relative Price Variability and Inflation

Recent literature has explained relative price variability within partial information multimarket equilibrium models. In these models the flow of information between individual goods markets is limited within a period and agents on individual markets suffer from aggregate-relative confusion (Cukierman 1983). The theoretical implication is that the variance of relative price forecast errors on local output is positively related to the variance of aggregate nominal and real shocks.

The hypothesis that unanticipated real and nominal shocks affect the structure of relative prices has received international empirical support. Most of the studies have used observed relative price variability as the dependent variable and regress it on variables representing nominal shocks such as unexpected inflation. However, the use observed relative price variability has the hidden assumption that all changes are surprise to economic agents. It does not allow to distinguish between expected and unexpected relative price changes.

The purpose of this study was to explore the hypothesis of a relationship between relative price variability and inflation in a context of high and volatile inflation. Peru's modern history has been marked by political and economic instability. The crisis that had started in the mid 1970's deepened at the end of the 1980's. Recurrent expansionary economic policies have run into foreign exchange crisis and subsequent stabilization episodes. But these numerous stabilization attempts since 1975 neither reduced inflation nor promoted sustained growth and by the end of the 1980's the Peruvian economy was facing the threat of hyperinflation.

Serious distortions in the relative price structure have accompanied inflation in the Peruvian economy. There is no general indexation mechanism that can ensure effective protection from inflation to both firms and workers. The resulted variability of relative price changes have been aggravated by inconsistent and unstable policies.

5.2 Empirical Analysis

The empirical analysis of the impact of the different components of inflation and other aggregate variables on relative price variability was carried out with monthly data on consumer price index from Peru for the period 1979:12 - 1988:07.

Two different type of models were estimated. The first models utilized followed the standard measure of observed relative price variability. In the second model, the conditional relative price variance and conditional variances of aggregate shocks were estimated following Engle's (1982) ARCH technique.

5.2.1 Observed Relative Price Variability and Inflation:

In the first model, observed relative price variability was measured as relative price change deviations from the mean. The explanatory variables used were expected and unexpected inflation, both obtain from an AR(5) model of inflation, and the real exchange rate and U.S. relative price variability. In addition a time lag of the dependent variable was used in the regressions.

The empirical results from the first model support the hypothesis that unexpected inflation was positively related to relative price change variability in the Peruvian economy during the period 1980:01 - 1988:07. Contrary to what some other empirical studies have found, the Peruvian data does not show that expected inflation affects relative price change variability. Thus, this analysis does not support the hypothesis of different speeds of adjustment among sectors in the economy in response to anticipated inflation.

With respect to external shocks, two additional variables were tested. The empirical findings suggest that U.S. relative price variability had no significant effect on domestic relative price variability; whereas the real exchange was found significant. The coefficient of real exchange rate show the expected negative sign and was larger in absolute value than the one of unexpected inflation.

5.2.2 Conditional Relative Price Variability

The second statistical model utilized incorporates different endogenous and exogenous variables, and in theory is testing the somewhat different hypothesis that changing conditional variances of inflation and other aggregate variables are inducing unexpected relative price variability. An ARCH regression model was used to estimate the conditional variances of 8 relative prices, domestic inflation, the real exchange rate and U.S. inflation. Using the conditional variances of the 8 relative prices an index of conditional relative price variance was constructed and used as the dependent variable.

The regressions results of this second models confirmed the main hypothesis of the study. The coefficients of the conditional variance of inflation and of the real exchange rate are positive and significant. The conditional variance of U.S. inflation was not found significant. Contrary to what was found in the first model, the coefficient of price variance is larger that the one of real exchange variance. It is important to notice that in the first model what is being evaluated is whether changes in the real exchange rate affect relative price variability and in the second model it is the variability of the exchange rate.

The regressions for the second model indicated that the lag structure of price uncertainty and the dependent variable is larger than for the first model. This results seems to make sense because the data used is on a monthly basis and one would expected some adjustment lags in the economy.

Although the first model has better statistical properties than the second one, using conditional relative price variability provides a more appropriate representation of the imperfect information approach than the observed relative price variability. The conditional relative price variance incorporates information about forecasting uncertainty of relative prices and supply conditions on individual markets.

5.3 Closing Remarks

There is general agreement that inflation reduces economic welfare because high inflation is associated with high uncertainty about inflation. The argument used in this study to explain how this association comes about is that a high and volatile inflation rate is accompanied by a high degree of dispersion of inflation rates across individual markets.

Two important conclusions can be derived from the empirical analysis of this hypothesis. First, during the period 1979:12-1988:07 unanticipated changes in the inflation rate and real exchange rate caused relative price variability that was not necessarily reflecting changes in supply and demand in the Peruvian economy. Second, that the positive relationship between inflation and relative price variability was confirmed in both cases, when inflation uncertainty was measured as unexpected inflation and when it was measured as the variance of inflation.

Attempts to control inflation by freezing prices have been followed by periods of high and volatile inflation during the period of analysis, failing to reduce uncertainty. Inflation uncertainty arises because high rates of inflation were increasing the probability that a counterinflationary policy will be implemented. This was hampering the ability of economic agents to respond to market signals and hence, resources were misallocated.

When an economy is near hyperinflation the national currency tends to be replaced by another instrument that does fulfill the functions of money particularly as a unit of account. As the prices of more goods become indexed to this unit (the dollar, for example), variability in relative prices is supposed to diminish. From this study it was observed that although inflation started to reach hyperinflationary levels, relative price variability was also increasing. Peru's high relative price variability at the end of 1988 constitutes indirect evidence of the lack of a generalized indexation to an alternative unit of account.

Finally, the conditional relative price variability can be used as an indicator of riskiness of supply conditions since it is measured as the average variance of relative price forecast errors on domestic markets. If economic agents are risk averse, then the long-run equilibrium output level will be negatively correlated with the level of relative price variability. A second step in the line of research of this thesis may be to test empirically this hypothesis in a future study.

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APPENDIX A.1

CONSUMER PRICE INDEX AND INFLATION RATE

month	year	Consumer Price Index	Inflation (Growth Rate)	Inflation (Log Diff.)
1	80	129.43	6.01	5.84
2	80	134.52	3.93	3.88
3	80	139.05	3.37	3.66
4	80	142.63	2.57	2.45
5	80	146.02	2.38	2.58
6	80	150.68	3.19	3.43
7	80	156.82	4.07	3.77
8	80	163.73	4.41	4.58
9	80	176.52	7.81	7.22
10	80	183.25	3.81	3.88
11	80	190.96	4.21	4.76
12	80	196.34	2.82	3.25
1	81	219.31	11.70	11.17
2	81	229.59	4.69	4.78
3	81	244.38	6.44	6.38
4	81	254.02	3.94	3.49
5	81	265.25	4.42	4.18
6	81	273.57	3.14	3.56
7	81	283.76	3.72	3.96
8	81	294.11	3.65	3.28
9	81	303.05	3.04	3.35
10	81	316.20	4.34	3.73
11	81	328.12	3.77	3.85
12	81	339.03	3.33	3.19
1	82	354.26	4.49	5.11
2	82	367.89	3.85	4.40
3	82	391.61	6.45	6.11
4	82	408.61	4.34	4.04
5	82	421.43	3.14	3.66
6	82	440.54	4.53	4.46
7	82	459.23	4.24	3.84
8	82	479.63	4.44	5.26
9	82	502.26	4.72	5.18
10	82	537.00	6.92	6.25
11	82	561.28	4.52	4.64
12	82	586.30	4.46	4.74

APPENDIX A.1

CONSUMER PRICE INDEX AND INFLATION RATE

month	year	Consumer Price Index	Inflation (Growth Rate)	Inflation (Log Diff.)
1	83	631.09	7.64	7.71
2	83	680.03	7.75	7.47
3	83	747.58	9.93	9.93
4	83	805.92	7.80	7.18
5	83	848.91	5.33	5.35
6	83	915.03	7.79	6.97
7	83	989.83	8.17	7.83
8	83	1076.97	8.80	7.74
9	83	1150.56	6.83	6.54
10	83	1206.51	4.86	4.34
11	83	1262.42	4.63	5.01
12	83	1319.56	4.53	4.82
1	84	1416.00	7.31	7.49
2	84	1534.00	8.33	7.32
3	84	1640.00	6.91	6.53
4	84	1732.00	5.61	5.60
5	84	1839.00	6.18	5.80
6	84	1948.00	5.93	5.76
7	84	2038.00	4.62	4.59
8	84	2195.00	7.70	7.63
9	84	2300.00	4.78	5.72
10	84	2428.00	5.57	5.86
11	84	2598.00	7.00	6.65
12	84	2790.00	7.39	8.01
1	85	3178.00	13.91	12.26
2	85	3481.00	9.53	8.68
3	85	3764.00	8.13	7.03
4	85	4224.00	12.22	11.42
5	85	4684.00	10.89	9.73
6	85	5236.00	11.78	10.66
7	85	5778.00	10.35	9.87
8	85	6402.00	10.80	9.84
9	85	6628.00	3.53	3.80
10	85	6825.00	2.97	3.23
11	85	7011.00	2.73	3.37
12	85	7206.00	2.78	3.27

APPENDIX A.1

CONSUMER PRICE INDEX AND INFLATION RATE

month	year	Consumer Price Index	Inflation (Growth Rate)	Inflation (Log Diff.)
1	86	7578.00	5.16	5.33
2	86	7898.00	4.22	5.27
3	86	8313.00	5.25	6.02
4	86	8650.00	4.05	4.15
5	86	8940.00	3.35	4.56
6	86	9258.00	3.56	3.58
7	86	9683.00	4.59	4.79
8	86	10067.00	3.97	4.17
9	86	10426.00	3.57	4.10
10	86	10839.00	3.96	5.15
11	86	11225.00	3.56	4.32
12	86	11739.00	4.58	3.94
1	87	12510.00	6.57	6.36
2	87	13210.00	5.60	5.44
3	87	13914.00	5.33	5.19
4	87	14832.00	6.60	6.39
5	87	15708.00	5.91	5.74
6	87	16444.00	4.69	4.58
7	87	17646.00	7.31	7.05
8	87	18946.00	7.37	7.11
9	87	20172.00	6.47	6.27
10	87	21456.00	6.37	6.17
11	87	22987.00	7.14	6.89
12	87	25182.00	9.55	9.12
1	88	28398.00	12.77	12.02
2	88	31758.00	11.83	11.18
3	88	38935.00	22.60	20.37
4	88	45911.00	17.92	16.48
5	88	49819.00	8.51	8.17
6	88	54210.00	8.81	8.45
7	88	70963.00	30.90	26.93
8	88	86366.00	21.71	19.64
9	88	184926.00	114.12	76.14
10	88	260009.00	40.60	34.08
11	88	323466.00	24.41	21.84
12	88	458895.00	41.87	34.97

APPENDIX A.1

CONSUMER PRICE INDEX AND INFLATION RATE

month	year	Consumer Price Index	Inflation (Growth Rate)	Inflation (Log Diff.)
1	89	676079.00	47.33	38.75
2	89	963260.00	42.48	35.40
3	89	1368166.00	42.03	35.09
4	89	2033561.00	48.63	39.63
5	89	2615413.00	28.61	25.16
6	89	3218301.00	23.05	20.74
7	89	4009407.00	24.58	21.98
8	89	5014288.00	25.06	22.36
9	89	6361132.00	26.86	23.79
10	89	7840168.00	23.25	20.91
11	89	9866060.00	25.84	22.98
12	89	13196060.00	33.75	29.08
1	90	17134757.07	29.85	26.12
2	90	22366023.99	30.53	26.64
3	90	29667504.53	32.65	28.25
4	90	40733483.72	37.30	31.70
5	90	54094066.38	32.80	28.37
6	90	77138138.66	42.60	35.49
7	90	125889442.29	63.20	48.98
8	90	625670528.18	397.00	160.34
9	90	1489095857.07	138.00	86.71
10	90	2918627879.86	96.00	67.29
11	90	4640618328.98	59.00	46.37
12	90	5740444872.95	23.70	21.27

Sources: Instituto Nacional de Estadistica, Lima, Peru.

APPENDIX A.2

Price Controls and their Administration, 1985-1990.

Category	Type of Products or Services	Weight in CPI	Methods of Setting and Readjustment
Controlled	Most sensitive foodstuffs	26%	Fixed by the government through CIPA. Raised only after requests from committees of producers
Regulated	Most manufactured goods	28%	Automatic increase permitted to a ceilling amount fixed monthly by MEF.
Supervised	Less sensitive agricultural products and services	24%	Based on supply and demand, but monitored by CIPA.
Special	Medicine and public utility tariffs.	22%	Individual procedures for each good, e.g. public utility commission for electricity.

Note: CIPA = Intersectoral Committee for Price Administration.
MEF = Ministry of Economics and Finance.
Source: Instituto Nacional de Estadistica, 1991.

The most sensitive prices, food and fuel prices, were "controlled". Less sensitive items, clothes, shoes, and household goods were among the items with "regulated" prices. Goods with regulated prices were eligible for automatic rather than discretionary, price increases, up to a ceiling amount fixed by the Ministry of Economy. Less sensitive agricultural product and services had "supervised" prices. These prices were set by market influences, that is, by supply and demand. Finally, there is a fourth category of prices called "special regime" that comprises prices of public utilities, transportation, medicicines, and rents. Here, individual procedures existed to control the price increases applicable to each item.

VITA

Rossana C. Polastri was born on November 24, 1960 in Culver City, Ca. In December 1985 received her B.S Degree in Economics from Universidad del Pacifico, Lima, Peru. From 1986 to 1988 she joined the Grupo de Analisis para el Desarrollo in Peru, as a Research Assistant. In 1988 she worked as a Reasearch Assistant at the Brookings Institution. Rossana completed her Masters Degree in Agricultural and Applied Economics at Virginia Tech in December of 1993 and is currently pursuing a Ph.D. in Economics at Virginia Tech.