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Contents

Abstract

The paper addresses several issues pertaining to the problem of monetary policy, inflation measurement, and relative prices. After some preliminary empirical analysis showing that the problem must be relevant we set out to conduct a mainly theoretical investigation. If the per period utility function is not homothetic in the commodity vector, empirical price aggregates do not have exact theoretical counterparts, and their properties, including those that are calculated from them (such as real interest rates), must be interpreted with care. We examine the consequences of goods heterogeneity in the framework of a stochastic dynamic equlibrium model without a steady state. To solve the model we posit specific, though we think plausible, assumptions concerning fiscal policy in a small open economy. Conclusions are obtained with important policy implications to the effect that inflation variability may be tolerated, and that the correct meaning and interpretation of real interest rates may run counter to accepted ideas. Our general conclusion is that neglecting goods heterogeneity may grossly mislead policy makers and analysts in certain circumstances.

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1 Introduction

We start from a few propositions related to monetary (exchange rate) policies and inflation, and which are applied, though not restricted, to transition countries in Central and Eastern Europe. 1. CPI inflation must be stable and low. 2. While the real exchange rate must be relatively stable, strict pegs should be avoided because they do not allow for monetary policy the opportunity to control inflation via controlling the real interest rate. 3. The conduct and/or evaluation of monetary policy must rely on a core, or underlying, inflation concept.

These propositions are not unanimously upheld, but each of them musters a significant degree of endorsement. Number 1 can be derived from the Maastricht criteria that are to be satisfied by countries wishing to join the European Union in the foreseeable future. Number 2 has acquired wide currency in general, and Number 3 has sneaked into central bank practice as well as it has held and gained ground in financial analyst and academic circles, respectively.

In this article we develop arguments to the effect that none of the above claims is unquestionable. We focus on transition countries, but many of our arguments must have broader validity. The main novelty of our approach lies in discarding the assumption of homothetic consumer preferences. We model an economy where consumers buy several goods (one of them durable) and services, and where their preferences are represented by the addilog utility function. This functional form has been used, for instance, by Clarida [1996] to estimate demand for imported durables, and by Bils-Klenow [1998] to test competing business cycle theories. One important empirical conclusion of these papers is that the non-homothetic preference specification seems to be confirmed. If we take this for granted then the observation that large and nontransitory relative price changes occur in reality raises the possibility that this can be important when we interpret CPI inflation as defined by the usual Laspeyres indexes. The present study offers an initial contribution to this direction via building a dynamic general equilibrium model of a small open economy.

We are faced with methodological difficulties in carrying out the proposed approach. As the model contains several types of goods that are and we assume both non-homothetic preferences and permanent productivity improvement there does not exist either a non-stochastic steady state or a balanced growth path in this model. Applying linear approximation methods, or nonlinear techniques that assume stationarity are not available options, therefore. Also we want to model a wide variety of shocks making thereby the state space is too large for the easy application of discrete nonlinear approximation methods. We generate (almost) exact formulas for price indexes, which are obtained by making specific behavioral assumptions concerning government (fiscal) policy. Essentially it is assumed that fiscal policy is set with a view towards controlling aggregate demand in a way that ensures the economy's solvency, and observes the rationality of individual decisions.

Section 2 reviews the story of Hungarian relative and absolute price changes in the 1990s. This is to be supplemented with evidence on transition and developed countries, showing that the Hungarian experience is generalizable. In Section 3 a stochastic general equilibrium model serving as a framework for the discussion in subsequent sections is set up and solved in two versions. In the light of these solutions Section 4 addresses the propositions described at the beginning of the introduction. First, we explore the consequences of our utility specification on the long term variability of prices. Second, we ask about the consequences of stabilizing prices when monetary policy makers are facing different kinds of shocks. Third, the meaning of real interest rates is analyzed. Finally, the various methodologies to calculate core inflation indexes are examined. Section 5 summarizes, and draws conclusions for further research.

2 The experience with inflation and with relative prices in Hungary

Inflation in transition has generated a substantial literature. (For summaries see Begg [1998], Cottarelli-Boyle [1999], Wyplosz [1999].) Here we describe some "internal" features of the inflationary process, having to do with relative price developments. We do not concern ourselves with the reasons for the ups and downs, or with the speed of disinflation etc. The focus will be on Hungary, salient features of price formation will be pointed out, then the more general transition literature will be invoked to show that these salient features are probably not particular to Hungary.

2.1 Relative consumer prices in Hungary

This subsection is based on Valkovszky-Vincze [2000]. The following is a short summary of relevant findings.[1]

The investigation was based on a database including the price indices of the 160 items making up the Hungarian consumer price index. Firstly we tried to identify "tradable" prices. We followed a statistical approach and came to the conclusion that all the goods classified as durable could pass as tradable, when this concept is defined as being well explained by nominal exchange rate changes in the long run. In other words the foreign exchange price of these goods seemed to be stable in the longer term. However, significant short run deviations could be observed, especially when unexpected changes happened to the path of the nominal exchange rate. Then we proceeded to investigate relative price changes. We could distinguish between six other subaggregates. First there are non-energy administered (regulated) prices, characterized by infrequent changes. Relative administered prices have exhibited a positive trend, and have grown substantially. They show a zigzag picture, undergoing short periods of large hikes, and more protracted periods of almost no change. Clearly the upward

[1] On this topic and also in general on the Hungarian CPI see Ferenczi-Valkovszky-Vincze [2000], too. About the behavior of relative prices in transition see Coorey-Mecagni-Offerdal [1998], and, on the case of Slovenia, Cufer-Mahadeva-Sterne [1998].

trend was due to the initial "underpricing" of public services, but the exact timing and size of the catching up process was politically motivated. Second came energy prices that have partly been regulated, but also exposed to world price developments, i.e. supply shocks from our point of view. The relative energy price was declining at a mild pace until 1995, when it rose steeply, followed by the continuation of an upward trend. This shape was due to deliberate policies, which had checked energy price increases before 1995 for social reasons, but the correction of the relative energy price was part of the fiscal adjustment package. The third category consisted of excisable goods. Excisable goods' relative prices do not show a zigzag pattern, but certain big changes have occurred in them. On the whole they exhibited a slightly negative relative price trend, which was notably reversed for some time in 1995. Again political motives were apparently behind the timing of changes. The fourth group included non-processed food prices. These seem to be relatively stable in the long term, but have had cycles, exhibiting not just very large short-term fluctuations, but fluctuations that have apparently been persistent. Fifth, we distinguished processed food prices that have been pretty stable in relative terms. Finally we could see as a different subcategory the remaining service prices. Their development almost mirrored that of durables, exhibiting a slight, but consistently positive, upward trend. This trend, and temporary variations, appeared to be related to wage changes, namely when the foreign exchange value of wages increased, the relative price of services became temporarily higher, suggesting that a Balassa-Samuelson type explanation can be invoked to explain the upward trend as well.

Indeed similar features of price formation are very likely to characterize the inflationary processes of other transition economies. In fact, administered public utility and energy relative prices exhibited the very same pattern also in the Czech and Slovak Republics, with the difference that an important upward adjustment of almost 50% took place in 1998-1999 and 1999-2000 respectively, while relative prices of this group followed a rather stable 2-3% per annum upward trend in Hungary and Poland throughout the last five years. The group of excisable goods revealed large relative price swings all over the Central and East-European countries (CEECs) admittedly in accordance with the hectic fiscal measures taken. In the second half of the nineties one can observe, however, a light upward trend in the relative price of alcoholic beverages and tobacco in many of the CEECs. Unfortunately, due to the lack of comparative databases, we were not able to repeat our study in its details with respect to other transition countries. Even if we cannot reproduce the distinction between processed and nonprocessed foodstuffs, on the basis of the Eurostat database, the whole group of foodstuffs featured as a very volatile part of the CPI basket, not only in the short, but also in the long run. In comparison, the relative price of foodstuffs in the UK has had a variance roughly 1/3 of the variance in Hungary in the same period. It is important to mention, that the relative food price movements of the countries concerned showed remarkable correlation. This fact suggests that not only (international) energy prices, but also food prices delivered symmetric external shocks to the region.

Though the following cannot do justice to the whole set of observations, the above description can be summarized in five important stylized facts.

1. A substantial part, especially those items that are relatively "durable", of the CPI in transition economies behaves like "textbook" tradables. There is evidence that short run unpredictable exchange rate changes are not passed onto domestic prices immediately, suggesting that at least a certain degree of nominal rigidity exists.

2. Prices that contain a substantial nontradable component, and are non-regulated, seem to conform with the Balassa-Samuelson hypothesis.

3. Agricultural prices impart substantial uncertainty to the CPI, and are heavily influenced by supply shocks. Supply shocks must be broadly understood, including not just changes in weather conditions, but the antics of politicians as well.

4. Public service and household energy prices have generally showed upward trends, with infrequent large changes, showing that both political considerations and the costs of changing prices must have played a substantial role in the catching up process of these prices.

5. There seems to be evidence that the income elasticities and intertemporal substitutabilities of the different subgroups are different. The expenditure share of durables has shown very large variations.

3 The model

Our goal is to build a model of a small open economy where consumers purchase four types of goods: 1. A tradable-durable good, 2. a nontradable-nondurable good, 3. a nondurable good with rigid but uncertain supply (called "food" hereinafter) , and 4. a public service. These goods have different income elasticities of demand, which in a growing economy implies that no convergence to stable ratios, i.e. stationary solution in growth rates, is available. To study the behavior of aggregate price indices, real interest rates, and possible "core inflation" measures we must construct a dynamic general equilibrium model. However, in order to focus on the above mentioned problems this model economy contains many simplifications with respect to things that are probably irrelevant tő the problems at hand, making the exercise, already rather complex, manageable. Simplifications include the following: there is no money or physical capital in the model, foreign demand plays a role only indirectly via the terms of trade effect, labor is supplied in a fixed quantity, international capital markets are passive, and the supply of "food" is exogenous. Also we make a shortcut to fiscal policy determination.

3.1 Household behavior

Households decide at the beginning of each period on how to divide their wealth among two financial assets (domestic government bonds (BH_t), and foreign bonds (BF_t)), and four consumption goods (nontradable consumption (CN_t), food (CA_t), a publicly provided service (CPI_t), and a durable good (D_t)). Labor supply is rigid, and normalized to 1. Disposable wealth includes assets carried over from the previous period, interest earned on them, profits distributed by firms owned by households, and wages paid out by the non-tradable sector and the tradable sector.

The representative household has a Houthakker (addilog) type per period utility function

$$U(CN_t, CA_t, CP_t, D_t) = \frac{CN_t^{1-\vartheta^N}}{1-\vartheta^N} + \frac{D_t{}^{1-\vartheta^D}}{1-\vartheta^D} + \frac{CA_t^{1-\vartheta^A}}{1-\vartheta^A} + \frac{CP_t{}^{1-\vartheta^P}}{1-\vartheta^P} \tag{1}$$

Thus we assume that services derived from possessing the durable good are proportional to its stock. We assume that ϑ^N,ϑ^D, ϑ^A and ϑ^P are definitely higher than 1, but ϑ^N,$\vartheta^D < \vartheta^A, \vartheta^P$ implying that the public service and foodstuffs have lower income elasticities than nontradables and durables. This statement is a consequence of a fundamental fact about addilog preferences.

Proposition 2 *If preferences belong to the addilog family, i and j are two goods, φ_i and φ_j are income elasticities of demand, and ϑ_i and ϑ_j are utility function parameters, respectively, then $\frac{\varphi_i}{\varphi_j} = \frac{\vartheta_j}{\vartheta_i}$. (See Chari-Kehoe [1999].)*

This is the reason why Bils-Klenow [1998]) call $\frac{1}{\vartheta_i}$ an index of luxuriousness. It must also be noted that their empirical results imply that luxuriousness and durability are positively correlated.

Then the household's program can be written as

$$\max E_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} U(CN_t, CA_t, CP_t, D_t) \right] \tag{2}$$

subject to

$$\begin{aligned} &BH_t + S_t BF_t + PN_t CN_t + PA_t CA_t + PP_t CP_t + T_t + \qquad (3)\\ &PI_t(D_t - (1-\delta^D)D_{t-1}) = I_{t-1}BH_{t-1} + S_t I^*{}_{t-1} BF_{t-1} + W_t + \Pi T_t + \Pi A_t \end{aligned}$$

By definition

$$D_t = ID_t + (1-\delta^D)D_{t-1} \tag{4}$$

where ID_t is the purchase of the durable good.

Let NW_t denote nominal wealth denominated in the home currency in period t. Then one can define the optimal value function in the usual way

$$V(NW_t) = \max_{CN_s, CA_s, CP_s, D_s, BF_s} E_t \left(\sum_{s=t}^{\infty} \beta^s U(CN_s, CA_s, CP_s, D_s) \right) \tag{5}$$

where

$$NW_t = I_{t-1}NW_{t-1} + (S_t I^*{}_{t-1} - I_{t-1})S_{t-1}BF_{t-1} + W_t + \Pi T_t + \Pi A_t + (1-\delta^D)PI_t D_{t-1} - I_{t-1}(PN_{t-1}CN_{t-1} + PA_{t-1}CA_{t-1} + PP_{t-1}CP_{t-1} + PI_{t-1}(D_{t-1} - (1-\delta^D)D_{t-2})) - T_t. \tag{6}$$

Under certain conditions this exists, and the Maximum Principle can be written as

$$V(NW_t, ...) = \max_{CN_s, CA_s, CP_s, D_s BF_t} (U(CN_t, CA_t, CP_t, D_t) + \beta E_t(V(NW_{t+1}, ...))) \tag{7}$$

The set of first order conditions for this problem can be derived by differentiating (5) with respect to the decision variables, making the first derivatives equal to zero, and using the envelope condition applied to (7).

Let us define the auxiliary variable Λ_t (the marginal indirect utility of nominal wealth in t). [2]

The following is the standard dynamic first order condition.

$$\Lambda_t = I_t \beta E_t(\Lambda_{t+1}). \tag{8}$$

It can be proved that

$$\Lambda_t = \frac{CN_t^{-\vartheta^N}}{PN_t} \tag{9}$$

Then we can obtain the following intratemporal first order conditions:

$$\frac{PN_t}{PA_t} = \frac{CN_t^{-\vartheta^N}}{CA_t{}^{-\vartheta^A}} \tag{10}$$

$$\frac{PN_t}{PP_t} = \frac{CN_t^{-\vartheta^N}}{CP_t{}^{-\vartheta^P}} \tag{11}$$

[2] This is the partial derivative of the value function associated to the consumer's problem with respect to nominal wealth.

$$\frac{PI_t}{PN_t} = \frac{D_t{}^{-\vartheta^D}}{CN_t^{-\vartheta^N}} + \beta(1-\delta^D)E_t(\frac{PI_{t+1}}{PN_{t+1}}\frac{CN_{t+1}^{-\vartheta^N}}{CN_t^{-\vartheta^N}}). \tag{12}$$

One can also derive from the optimal choice between domestic and foreign bonds, the portfolio choice equation:

$$E_t(\Lambda_{t+1}(I_t - I_t^* \frac{S_{t+1}}{S_t}) = 0. \tag{13}$$

The transversality condition may be written as

$$\lim_{T\to\infty} E_t \left[\frac{\beta^{T-t}\Lambda_{t+T}}{\Lambda_t} NW_{t+T}\right] = 0.$$

for all T.

3.2 Production

Production has a hierarchical structure. Differentiated producers produce a continuum of tradable goods using homogenous labor with a diminishing returns to scale technology. We assume that tradable producers are distributed on $[0,1]$ uniformly. This output can be sold domestically or exported. If sold domestically a competitive sector aggregates these differentiated products into a domestically produced tradable aggregate. Then another competitive sector produces, via a CES technology, an intermediate input-capital good aggregate of this domestic tradable aggregate and of an imported good. Nontradables are made of this latter good and by homogenous labor via a Cobb-Douglas technology. In addition, the food product is produced randomly, and a public good service is provided at zero cost.

3.2.1 The tradable sector

We assume that the production function is

$$QT_{jt} = \theta_t LT_{jt}{}^{\alpha}, \tag{14}$$

where QT_{jt} is the quantity of output, LT_{jt} labor, θ_t and α are production function parameters.

Output can be sold either domestically, or abroad (exports).

$$QT_{jt} = X_{jt} + Z_{jt}, \tag{15}$$

where X_{jt} is domestic purchases, and Z_{jt} exports.

First let us assume that prices are flexible, and firms can set period t prices based on current information.

Firms are assumed to be price taker on the international markets, and price makers at home. A firm entering period $t+1$ has to decide on how much to produce and what price to charge at home. This assumption implies the ability to price-discriminate, and leads to a higher domestic price at home than abroad. Thus if the firm produces a certain amount of its product and faces the problem of dividing it between domestic sales and exports it will first satisfy domestic demand and export the rest. The possibility of international price discrimination can be explained by the presence of transportation and other transaction costs, tariffs etc. that make perfect arbitrage impossible. This problem can be written therefore as

$$\max_{PQ_{jt},LT_{jt},} PX_t(\theta_t {LT_{jt}}^{\alpha} - X_{jt}) + PQ_{jt}X_{jt} - W_t LT_{jt}, \tag{16}$$

where PQ_{jt} is the domestic price, and W_t the nominal wage. Moreover

$$PX_t = PX_t^* S_t \tag{17}$$

is the (common) export price expressed in domestic currency, PX_t^* is the export price in foreign currency and S_t is the nominal exchange rate. To carry out maximization the firm must take into account the demand function (see below). The demand function, which is supposed to be known by the seller, has a price elasticity ϕ which is identical across firms. Then monopoly profit maximization implies the following formula. for domestic tradable prices

$$PQ_{jt} = PX_t \frac{\phi}{\phi - 1}. \tag{18}$$

In this formula the role of marginal cost is assumed by the exchange rate, which is the marginal opportunity cost of selling at the domestic market.

Then labor demand can be explicitly expressed from the other first order condition as

$$LT_{jt} = (\frac{\alpha \theta_t PX_t}{W_t})^{\frac{1}{1-\alpha}}. \tag{19}$$

Our formulation of international price discrimination implies that the elasticity of demand for the domestic tradable is higher abroad than at home.

Now we can consider nominal rigidity in price setting, by assuming that period $t+1$ prices must be set based on period t information. There is change in only one equation, namely the equation determining home-produced tradable prices. The new formula is the following:

$$PQ_{t+1} = \frac{\phi}{\phi - 1} \frac{E_t(S_{t+1} PX^*_{t+1} \Lambda_{t+1})}{E_t(\Lambda_{t+1})}. \tag{20}$$

Thus the marginal opportunity cost, the variable to be marked up, is modified by taking uncertainty into account. The effective marginal opportunity cost $(\frac{E_t(PX^*_{t+1} S_{t+1} \Lambda_{t+1})}{E_t(\Lambda_{t+1})})$ is higher (lower) than the expected export price if the export price and the marginal utility of nominal wealth are positively (negatively) correlated since

$$\frac{E_t(PX^*_{t+1} S_{t+1} \Lambda_{t+1})}{E_t(\Lambda_{t+1})} = E_t(PX^*_{t+1} S_{t+1}) + \frac{cov_t(\Lambda_{t+1}, PX^*_{t+1} S_{t+1})}{E_t(\Lambda_{t+1})}$$

As usual if shocks are small in the sense that $PX^*_{t+1} S_{t+1} \leq PQ_{j,t+1}$ for sure then it is ex post rational to satisfy domestic demand at the predetermined prices. In the following it is always assumed to be the case.

Assuming tradable firms are uniformly distributed on the interval $[0, 1]$ the aggregate input demand functions are exactly the same as that of the individual demand functions, with the superscripts omitted.

To derive the demand elasticity we start with the Dixit-Stiglitz technology for the aggregate home tradable good

$$X_t = \left(\int (X_{jt})^{\nu} \, dj \right)^{\frac{1}{\nu}}. \tag{21}$$

Then the aggregate domestic tradable price index PQ_t can be written as

$$PQ_t = \left(\int (PQ_{jt})^{\frac{\nu}{\nu-1}} \, dj \right)^{\frac{\nu-1}{\nu}} \tag{22}$$

and the demand for the jth good as

$$X_{jt} = \left(\frac{PQ_{jt}}{PQ_t} \right)^{\frac{1}{\nu-1}} X_t \tag{23}$$

Thus $\phi = \frac{1}{\nu-1}$.

To complete our description of the intermediate-capital good (tradable) sector we define a CES technology as follows:

$$Y_t = {X_t}^{\rho} {M_t}^{1-\rho}. \tag{24}$$

Then price and demands can be derived as

$$PI_t = \rho^{-\rho} (1-\rho)^{1-\rho} {PM_t}^{\rho} PQ_t^{1-\rho} \tag{25}$$

$$X_t = (1-\rho)\frac{PI_t}{PQ_t}Y_t \tag{26}$$

$$M_t = \rho\frac{PI_t}{PM_t}Y_t \tag{27}$$

where

$$PM_t = PM_t^* S_t \tag{28}$$

is the import price in domestic, and PM_t^* the import price in foreign currency.

3.2.2 The non-tradable sector

The Cobb-Douglas technology can be written as

$$QN_t = {LN_t}^{\eta} YN_t^{1-\eta} \tag{29}$$

thus prices and demand satisfy

$$PN_t = \eta^{\eta}(1-\eta)^{1-\eta}{W_t}^{\eta}PI_t \tag{30}$$

$$LN_t = (1-\eta)\frac{PN_t}{W_t}QN_t \tag{31}$$

$$YN_t = \eta\frac{PN_t}{PI_t}QN_t. \tag{32}$$

3.2.3 Food sector

Here we assume that food products cannot be either exported or imported, and decisions are taken one period in advance, before the realization of technological uncertainty. (Alternatively technological uncertainty can be reinterpreted as involving quotas.) Output is purely stochastic, and it is equal to consumption.

$$QA_t = CA_t. \tag{33}$$

3.2.4 Public service sector

Provision of the public service (QP_t) requires tradable input proportionally, and is supplied elastically to satisfy household demand for it.

$$YP_t = QP_t, \tag{34}$$

$$QP_t = CP_t, \tag{35}$$

where YP_t is input demand for tradables, and CP_t household demand for the public service.

3.3 Market equilibrium

3.3.1 Goods markets

There is a nontrivial good market, for the intermediate-capital good, and a trivial one for the nontradable good. Market clearing requires

$$Y_t = YN_t + ID_t + YP_t \tag{36}$$

and

$$QN_t = CN_t. \tag{37}$$

3.3.2 Labor market

Labor market equilibrium is equivalent to

$$1 = LN_t + LT_t. \tag{38}$$

3.4 Exogenous variables

Exogenous variables of the model include the (euro) import price, the (euro) export price, the (euro) interest rate, productivity in the home tradable sector, and food supply ($PM_t^*, PX_t^*, I^*{}_t, \theta_t, CA_t$).

3.5 Policy

Government policy has three aspects that are, however, interrelated. Policy is generically defined in the following way.

$$f_P(PM_t^*, PX_t^*, I_t^*, \theta_t, CA_t, \Omega_{t-1}),$$

where Ω_{t-1} is the set of period $t-1$ variables. In other words the government can set these variables based on past information as well as on the current realization of shocks.

3.5.1 Pricing of the public service

Efficiency would require setting

$$PP_t = PI_t. \tag{39}$$

However, we assume that public service prices must be predetermined, and cannot adjust to shocks immediately. Also we allow for the possibility the government may wish to deviate prices from marginal costs for reasons of taxation. Thus we assume the existence of a general relationship such as

$$PP_{t+1} = F_{PP}(\Omega_{t-1})E_t(PI_t). \tag{40}$$

Here $F_{PP}(\Omega_{t-1})$ is assumed to be a stationary markup. One can see that variation in the price level due to changing the markup can be achieved by the government, if monetary policy does not strive to dampen it. However, this should not involve conditional variability, i.e. price level uncertainty, whatever the nominal exchange rate policy is.

3.5.2 Demand management

Let us define the marginal utility of nominal euro wealth as

$$\Lambda_t^e = S_t \Lambda_t. \tag{41}$$

The government is supposed to be able to set the marginal utility of nominal euro wealth as

$$\Lambda_t^e = f_{PD}(\Omega_{t-1}, PM_t^*, PX_t^*, I^*{}_t, \theta_t, CA_t) \tag{42}$$

under the implementability constraint.

$$\Lambda_t^e = \beta I_t^* E_t(\Lambda_{t+1}^e). \tag{43}$$

Our shortcut to policy determination means that via these instruments the government can, to a certain extent, control the marginal utility of euro wealth in the economy. Euro wealth is a real variable for a small open economy, and ut is generally believed that domestic spending is an important concern for governmentsin countries where foreign debt is not insignificant. The exogeneity of foreign interest rates makes the debt process of small open economies inherently unstable, thus some feedback regulation by the government may indeed be necessary. (See below about the feasibility of this policy formulation.)

3.5.3 Monetary (exchange rate) policy

Monetary policy has two varieties:

Fixed exchange rate:

$$S_t = 1, \tag{44}$$

and flexible exchange rates

$$S_t = F_{pM}(\Omega_{t-1}, PM_t^*, PX_t^*, I^*{}_t, \theta_t, CA_t). \tag{45}$$

In this model trends in the nominal exchange rate do not make sense, thus the exchange rate is supposed to be stationary. Identifying monetary policy with exchange rate policy in this model without money is more attractive than the alternative of identifying it with interest rate policy, since it avoids questions of indeterminacy. Defining exchange rate flexibility simply by allowing for its response to shocks seems also plausible.

3.6 Solution of the model

The endogenous part can be solved in the following order. A first set of equations can be solved from the exogenous and policy processes directly.

$$PM_t = PM_t^* S_t \tag{46}$$

$$PX_t = PX_t^* S_t \tag{47}$$

For the fully flexible price version

$$PQ_t = PX_t \frac{\phi}{\phi - 1}, \tag{48}$$

whereas in the version with nominal price rigidity

$$PQ_t = \frac{\phi}{\phi - 1} \frac{E_{t-1}(PX_t^* \Lambda_t^e)}{E_{t-1}(\frac{\Lambda_t^e}{S_t})}. \tag{49}$$

The expectations on the right-hand side depend only on exogenous and policy variables, thus can be calculated if those processes are known. The next block of equations includes

$$PI_t = \rho^\rho (1-\rho)^{1-\rho} PM_t{}^\rho PQ_t^{1-\rho} \tag{50}$$

$$PA_t = \frac{CA_t^{-\vartheta^A} S_t}{\Lambda_t^e} \tag{51}$$

$$CP_t = (\frac{\Lambda_t^e}{S_t} PP_t)^{-\frac{1}{\vartheta^P}} \tag{52}$$

$$I_t = \frac{I^*{}_t}{S_t} \frac{E_t(\Lambda_{t+1}^e)}{E_t(\frac{\Lambda_{t+1}^e}{S_{t+1}})}. \tag{53}$$

Again the right-hand side expectations are computable from the exogenous and policy processes.

Then the labor market equilibrium can be used to determine nominal wages as a function of formerly solved for variables.

$$1 = (\frac{\alpha\theta_t PX_t}{W_t})^{\frac{1}{1-\alpha}} + \frac{\left[\eta^\eta(1-\eta)^{1-\eta}(1-\eta)PI_t\right]^{\frac{\eta\vartheta^N-\eta}{\vartheta^N}} S_t}{W_t^{\frac{\vartheta^N-\eta\vartheta^N+\eta}{\vartheta^N}} \Lambda_t^e}. \tag{54}$$

This is an implicit equation that cannot be solved explicitly. If it is solved for W_t the rest of the system can be computed recursively. Regarding this equation as a function of W_t (the other variables are predetermined and positive) then $\frac{\vartheta^N-\eta\vartheta^N+\eta}{\vartheta^N} > 0$ implies that the right hand side is monotonically decreasing, it approaches ∞ as W_t approaches 0, and approaches 0 as W_t approaches ∞. Thus there is an unique solution.

$$LT_t = (\frac{\alpha\theta_t PX_t}{W_t})^{\frac{1}{1-\alpha}} \tag{55}$$

$$QT_t = \theta_t {LT_t}^\alpha \tag{56}$$

$$PN_t = \eta^\eta(1-\eta)^{1-\eta} {W_t}^\eta PI_t \tag{57}$$

$$CN_t = (\frac{\Lambda_t^e}{S_t} PN_t)^{-\frac{1}{\vartheta^N}} \tag{58}$$

$$LN_t = (1-\eta)\frac{PN_t}{W_t} CN_t \tag{59}$$

$$YN_t = \eta \frac{PN_t}{PI_t} CN_t \tag{60}$$

$$D_t = \left[\frac{PI_t \Lambda_t^e}{S_t} (1 - \beta(1 - \delta^D) E_t(\frac{PI_{t+1} \Lambda_{t+1}^e S_t}{PI_t \Lambda_t^e S_{t+1}})) \right]^{-\frac{1}{\vartheta^D}} \tag{61}$$

The expectation $E_t(\frac{PI_t \Lambda_{t+1}^e S_t}{PI_t \Lambda_t^e S_{t+1}})$ can be computed again from the basic processes.

The rental price of durables may be defined as

$$PR_t = PI_t(1 - \beta(1 - \delta^D) E_t(\frac{PI_{t+1} \Lambda_{t+1}^e S_t}{PI_t \Lambda_t^e S_{t+1}})). \tag{62}$$

Then the rest of the system may be written as

$$ID_t = D_t - (1 - \delta^D) D_{t-1} \tag{63}$$

$$Y_t = YN_t + ID_t + CP_t \tag{64}$$

$$X_t = (1 - \rho) \frac{PI_t}{PQ_t} Y_t \tag{65}$$

$$M_t = \rho \frac{PI_t}{PM_t} Y_t \tag{66}$$

$$Z_t = QT_t - X_t. \tag{67}$$

3.6.1 Justifying the solution

The above formulas refer to a subset of the variables of the model. Ominously we have not imposed any feasibility constraints on the equilibrium processes. To make economic sense, the resulting equilibrium must satisfy transversality or no-Ponzi game conditions for both the private sector and the government. We also left open the problem of portfolio decisions, in other words the behavior of capital markets. To argue for the validity of the (sub)solution we obtained we proceed via several steps.

1. How does the long-run financial position of the private sector behave for a given demand policy? It is clear that different demand policies would lead to quite different present values of net future spending. In other words any randomly selected aggregate demand policy that satisfies the implementability condition is very unlikely to result in a feasible equilibrium.

2. Can the government make any private income-spending plan feasible? The answer is yes, provided that the government has the ability to adjust (lump-sum) taxes appropriately. With no restriction on taxes, the government can make a transfer each period that balances private sector accounts so that no borrowing or lending by households occur.

3. Is this enough to make the proposed equilibrium feasible for the whole economy? As transfers between the government and the private sector do not affect the overall budget constraint, an arbitrary (implementable) aggregate demand policy is still vulnerable to being nonfeasible for the economy as a whole. However, the government has another instrument, namely real government spending. Suppose the government spends on importables, which may even enter the household utility function in an additive way, i.e. by not influencing the marginal utilities of privately purchased goods. Then the government can adjust its own spending so that the the current account be zero at each period.[3]

Thus one can prove that there exist, in fact many must exist, government policies that support an equilibrium for a given (implementable) aggregate demand policy. These policies also imply zero asset trade in equilibrium. In fact in equilibrium models with government spending it is obviously the case that government spending has an impact on private consumption. Thus simply stated our assumption is as follows: the government can control aggregate demand constrained by the implementability condition. If we were interested in optimal policy analysis we should specify the welfare consequences of fluctuations in government spending, or should try to model a realistic tax structure. These considerations are not necessary for our present purposes. Also, it may be feared that some demand policies would have widely unrealistic consequences for the path of government spending and taxes. Therefore, if one would wish to carry out numerical calculations with the model, attention should be restricted to policies that are reasonable in a vague sense, i.e. they are well-interpretable demand policies involving parameters that do not result in extreme fluctuations either in expenditures or in taxes.

3.7 Price formulas

Above we showed how the model can be solved recursively. Here, we derive the formulas for prices expressed as functions of policy and exogenous variables as far as it is possible or convenient.

[3] Nonnegativity constraints should be observed, of course.

Food prices are

$$PA_t = \frac{CA_t^{-\vartheta_a} S_t}{\Lambda_t^e}. \tag{68}$$

Written in logs

$$pa_t = -\vartheta_a ca_t - \lambda_t^e + s_t \tag{69}$$

where lower case letters denote logs of the corresponding variable.

Thus one can see that food prices are determined by monetary policy, demand policy and the agricultural supply shock, and the latter's impact depends on the ϑ_a parameter. When this is large, i.e. foodstuffs are less luxurious, then supply shocks have larger impacts on both absolute and relative food prices.

Flexible durable prices can be expressed as

$$PI_t = \rho^\rho (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi - 1} PX_t^* \right)^{1-\rho} S_t, \tag{70}$$

or in logs

$$pi_t = \log(\rho^\rho (1-\rho)^{1-\rho}) + \rho pm_t^* + (1-\rho) \log(\frac{\phi}{\phi - 1}) + (1-\rho) px_t^* + s_t. \tag{71}$$

One can see that with full price flexibility demand policy has no impact on durable prices, though exchange rates have an unitary elasticity. In this case import and export prices contribute to durable price inflation with weights corresponding to the import share, and 1 minus the import share in the intermediate sector. The $(1-\rho)\log(\frac{\phi}{\phi-1})$ term expresses the fact that durable prices have a higher level when there is a larger domestic distortion as expressed by the mark-up term in the pricing formula for tradable production.

In the case of price rigidity the formula becomes

$$PI_t = \rho^\rho (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi - 1} \frac{E_{t-1}(PX_t^* \Lambda_t^e)}{E_{t-1}(\frac{\Lambda_t^e}{S_t})} \right)^{1-\rho} S_t^\rho. \tag{72}$$

A second order approximation (exact in the case of lognormality) gives

$$\begin{aligned} pi_t = {} & \log(\rho^\rho (1-\rho)^{1-\rho}) + \rho pm_t^* + (1-\rho) \log(\frac{\phi}{\phi - 1}) + \rho s_t + \\ & (1-\rho)(E_{t-1}(px_t^* + s_t) + \frac{1}{2} var_{t-1} px_t^* + \frac{1}{2} var_{t-1} s_t + \\ & cov_{t-1}(\lambda_t^e, px_t^*) - cov_{t-1}(\lambda_t^e, s_t)). \end{aligned} \tag{73}$$

The direct impact of the exchange rate is blunted, as it manifests itself only via the import price. However, both monetary and demand policy expectations matter. The expected exchange rate has a direct positive impact, and, in addition, exchange rate variability adds to the price level as well. We can call monetary and fiscal policies *parallel* if devaluations tend to be accompanied by expansionist aggregate demand policies. Parallelism means that $cov_{t-1}(\lambda_t^e, s_t)$ is negative in our model. Thus tradables prices become relatively higher when policy exhibits parallelism.

The price that enters the first order condition (the demand function) for durables involves the rental price. In the flexible case this may be written as

$$PR_t = \left(\rho^\rho (1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi - 1} PX_t^* \right)^{1-\rho} S_t \right) x \tag{74}$$
$$\left(1 - (1-\delta^D) E_t \left(\frac{\beta \Lambda_{t+1}^e}{\Lambda_t^e} \left[\frac{PM_{t+1}^{*}{}^\rho PX_{t+1}^{*1-\rho}}{PM_t^{*\rho} PX_t^{*1-\rho}} \right] \right) \right)$$

If we use the notation $H_t = 1 - (1-\delta^D) E_t \left(\frac{\beta \Lambda_{t+1}^e}{\Lambda_t^e} \left[\frac{PM_{t+1}^{*}{}^\rho PX_{t+1}^{*1-\rho}}{PM_t^{*\rho} PX_t^{*1-\rho}} \right] \right)$, then taking logs yields

$$pr_t = \log(\rho^\rho (1-\rho)^{1-\rho}) + \rho pm_t^* + (1-\rho) \log(\frac{\phi}{\phi-1}) + (1-\rho) px_t^* + s_t + h_t. \tag{75}$$

The h_t term can be approximated as

$$\begin{aligned} -h_t \approx \; & \log(1-\delta^D) + \log\beta + E_t(\lambda_{t+1}^e - \lambda_t^e) + \\ & \rho E_t(pm_{t+1}^* - pm_t^*) + (1-\rho) E_t(px_{t+1}^* - px_t^*) + \\ & \frac{1}{2} \left[var_t(\lambda_{t+1}^e) + \rho var_t(pm_{t+1}^*) + (1-\rho) var_t(px_{t+1}^* \right] + \\ & \rho cov_t(\lambda_{t+1}^e, pm_{t+1}^*) + (1-\rho) cov_t(\lambda_{t+1}^e, px_{t+1}^*) \\ & + \rho(1-\rho) cov_t(px_{t+1}^*, pm_{t+1}^*), \end{aligned} \tag{76}$$

where there is a constant factor (omitted) that is time invariant if h_t is stationary as in Clarida [1996]. Here h_t is the deviation of the rental price from the purchase price. Interestingly in the price flexibility case this deviation does not depend on exchange rate policy. However, it depends on demand policy. An expected contraction, i.e. a positive $E_t(\lambda_{t+1}^e - \lambda_t^e)$, depresses the rental price, by making the possession of the durable good less valuable in the future. Expected increases in export and import prices have the same qualitative effect. In addition demand policies that depend on foreign prices also make a contribution. Suppose, for example, that an increase in import prices is associated with a decline in aggregate demand, i.e. $\rho cov_t(\lambda_{t+1}^e, pm_{t+1}^*)$ is positive. This again decreases the rental price, by making the purchase of the durable good a risky investment. On the other hand the plausible policy of an aggregate demand expansion followed upon an export price increase would make the purchase a hedge against future uncertainties, and would result in a decline in the rental price.

With price rigidity things get to be messy

$$PR_t = \left(\rho^{\rho}(1-\rho)^{1-\rho} PM_t^{*\rho} \left(\frac{\phi}{\phi - 1} \frac{E_{t-1}(PX_t^* \Lambda_t^e)}{E_{t-1}(\frac{\Lambda_t^e}{S_t})} \right)^{1-\rho} S_t^{\rho} \right) x \tag{77}$$

$$\left(1 - (1-\delta^D) E_t \left(\frac{\beta \Lambda_{t+1}^e S_t^{1-\rho}}{\Lambda_t^e S_{t+1}^{1-\rho}} \left[\frac{PM_{t+1}^{*\rho} \left(\frac{E_t(PX_{t+1}^* \Lambda_{t+1}^e)}{E_t(\frac{\Lambda_{t+1}^e}{S_{t+1}})} \right)^{1-\rho}}{PM_t^{*\rho} \left(\frac{E_{t-1}(PX_t^* \Lambda_t^e)}{E_{t-1}(\frac{\Lambda_t^e}{S_t})} \right)^{1-\rho}} \right] \right) \right).$$

Now the log of the rental prices may be written as

$$\begin{aligned} pr_t &= \log(\rho^{\rho}(1-\rho)^{1-\rho}) + \rho pm_t^* + (1-\rho)\log(\frac{\phi}{\phi-1}) + \rho s_t + \\ &(1-\rho)E_{t-1}\left(px_t^* + s_t\right) + \frac{1}{2} var_{t-1} px_t^* + \frac{1}{2} var_{t-1} s_t \\ &+ cov_{t-1}(\lambda_t^e, px_t^*) - cov_{t-1}(\lambda_t^e, s_t) + h_t. \end{aligned} \tag{78}$$

The approximation of h_t yields

$$\begin{aligned} -h_t \approx\; & \log(1-\delta^D) + \log\beta + E_t(\lambda_{t+1}^e + \rho pm_{t+1}^* - (1-\rho)s_{t+1}) - \\ & (\lambda_t^e + \rho pm_t^* - (1-\rho)s_t) + \\ & \frac{1}{2} var_t(\lambda_{t+1}^e + \rho pm_{t+1}^* - (1-\rho)s_{t+1}) + \\ & (1-\rho)E_t\left(px_{t+1}^* + s_{t+1}\right) + \frac{1}{2} var_t px_{t+1}^* + \frac{1}{2} var_t s_{t+1} \\ & + cov_t(\lambda_{t+1}^e, px_{t+1}^*) - cov_t(\lambda_{t+1}^e, s_{t+1}) - \\ & (1-\rho)E_{t-1}\left(px_t^* + s_t\right) + \frac{1}{2} var_{t-1} px_t^* \\ & + \frac{1}{2} var_{t-1} s_t + cov_{t-1}(\lambda_t^e, px_t^*) - cov_{t-1}(\lambda_t^e, s_t) \end{aligned} \tag{79}$$

Here the main novelty is that both exchange rate and exchange rate policy expectations play some role.Different exchange rate policies may imply either an increase or a decrease in the riskiness of investing in durables.

Public service prices are set by policy makers as

$$PP_t = F_{PP}(\Omega_{t-1})E_{t-1}(PI_t). \tag{80}$$

The approximation results in

$$pp_t = f_{PP}(\Omega_{t-1}) + E_{t-1}(pi_t) + \frac{1}{2}var_{t-1}(pi_t). \tag{81}$$

One can see that expected intermediate good prices play a role here, and unexpected changes in the exchange rate have no effect, Thus this pricing assumption gives another source of price rigidity, irrespective of the pricing behavior of tradable producers.

For wages one cannot give an explicit expression, but can determine the sign of partial derivatives unambiguously. The implicit equation to be solved is

$$(\frac{\alpha\theta_t PX_t}{W_t})^{\frac{1}{1-\alpha}} + \frac{\left[\eta^\eta(1-\eta)^{1-\eta}(1-\eta)PI_t\right]^{\frac{\eta\vartheta^N-\eta}{\vartheta^N}} S_t}{W_t^{\frac{\vartheta^N-\eta\vartheta^N+\eta}{\vartheta^N}}\Lambda_t^e} - 1 = 0$$

in both the flexible and rigid cases. However, the comparative statics is different in the two cases. When tradable prices are flexible
$\partial W_t/\partial S_t = 1$ $\quad \partial\frac{W_t}{S_t}/\partial\theta_t > 0$ $\quad \partial\frac{W_t}{S_t}/\partial PX_t^* > 0$ $\quad \partial\frac{W_t}{S_t}/\partial PM_t^* > 0$ $\quad \partial\frac{W_t}{S_t}/\partial\Lambda_t^e < 0$.

In other words the exchange rate has an unitary elasticity, and the foreign price, productivity and aggregate demand variables influences the euro wage directly, i.e. independently of exchange rate policy. All signs are just as expected. The main difference in the price rigidity case is that $\partial W_t/\partial S_t < 1$. The other derivatives should be written in terms of the nominal wage
$\partial W_t/\partial\theta_t > 0$ $\quad \partial W_t/\partial PX_t^* > 0$ $\quad \partial W_t/\partial PM_t^* > 0$ $\quad \partial W_t/\partial\Lambda_t^e < 0$.

These signs can be interpreted as incipient changes in the euro wage as well, but in contrast to the price flexibility case exchange rate policy can undo any of these. In general one can make a loglinearization that results in the following formula

$$w_t = a_0 s_t + a_1\log\theta_t + a_2 px_t^* + a_3 pm_t^* - a_3\lambda_t^e, \tag{82}$$

where a_1, a_2, a_3, a_4 are positive, time-varying and proportional to the corresponding derivatives, whereas a_0 equals 1 in the flexible case, and positive but less than 1 in the rigidity case.

Nontradable prices in the case of full price flexibility may be expressed as

$$PN_t = \eta^\eta(1-\eta)^{1-\eta}W_t{}^\eta\left[\rho^\rho(1-\rho)^{1-\rho}(PM_t^*)^\rho\left(\frac{\phi}{\phi-1}PX_t^*\right)^{1-\rho}S_t\right]^{1-\eta}. \tag{83}$$

The loglinear approximation gives

$$pn_t = s_t + \log(\eta^\eta(1-\eta)^{1-\eta}) + \eta(a_1 \log\theta_t - a_3\lambda_t^e) + \\ \log(\rho^\rho(1-\rho)^{1-\rho}) + (1-\rho)\log\frac{\phi}{\phi-1} + (\rho(1-\eta)+\eta a_3)pm_t^* + \\ ((1-\rho)(1-\eta)+\eta a_2)px_t^* \tag{84}$$

The formula is straightforward: nontradable prices are influenced by two real variables, those that enter the formula for nominal wages, i.e. productivity and aggregate demand.

With rigid home tradable prices

$$PN_t = \eta^\eta(1-\eta)^{1-\eta}W_t{}^\eta \left[\rho^\rho(1-\rho)^{1-\rho}PM_t^{*\rho}\left(\frac{\phi}{\phi-1}\frac{E_{t-1}(PX_t^*\Lambda_t^e)}{E_{t-1}(\frac{\Lambda_t^e}{S_t})}\right)^{1-\rho} S_t^\rho\right]^{1-\eta}. \tag{85}$$

The approximation can be written as

$$pn_t = (\eta+\rho-\eta\rho)s_t + \log(\eta^\eta(1-\eta)^{1-\eta}) + \eta(a_1\log\theta_t + a_2 px_t^* - a_3\lambda_t^e) + \\ \log(\rho^\rho(1-\rho)^{1-\rho}) + (1-\rho)\log\frac{\phi}{\phi-1} + \rho(1-\eta)pm_t^* + \\ (1-\rho)(E_{t-1}(px_t^*+s_t) + \frac{1}{2}var_{t-1}px_t^* + \frac{1}{2}var_{t-1}s_t + \\ cov_{t-1}(\lambda_t^e, px_t^*) - cov_{t-1}(\lambda_t^e, s_t)). \tag{86}$$

Again the exchange rate's elasticity is less than 1. Also uncertainty affects prices by generating risk premium terms. One can find again that parallel policies result in higher prices, or expressing it in a different manner, increased parallelism leads to higher inflation. This means accidentally that if policy is supposed to turn from antiparallelism to something like no parallelism then this would raise inflation in the nontradable sector.

From the formulas it can be seen that the aggregate demand variable has an effect on relative prices, irrespective of price rigidity. Also exchange rate policy has an impact on contemporaneous relative prices.

4 Analysis

4.1 Long run volatility of the price level

In our model no exact aggregate price index exists. Aggregate CPI indexes used in practice are Laspeyres-type indexes where individual price indices are averaged by applying past relative expenditures as weights. This would give an exact price index only if preferences belonged to the generalized Leontief-type. (See Pollak [1983].) If relative expenditures change then the impact of any of our four price indexes on the aggregate CPI changes, too. We can create plausible conditions under which, as the economy grows, the expenditure weights on food and public services converge to 0. For the sake of a simple demonstration let us suppose now that $\vartheta_N = 1$, i.e. nontradable consumption enters the utility function as a logarithm. Then

$$PN_tCN_t = \frac{S_t}{\Lambda_t^e}$$

and

$$PA_tCA_t = \frac{CA_t^{1-\vartheta_a}S_t}{\Lambda_t^e}$$

imply that

$$\frac{PA_tCA_t}{PN_tCN_t} = CA_t^{1-\vartheta_a}.$$

Then this ratio approaches 0, if the growth rate of the exogenous supply of food is lower than $\vartheta_a - 1$.

For the public service

$$PP_tCP_t = \Lambda_t^{e-\frac{1}{\vartheta P}} S_t^{\frac{1}{\vartheta P}} PP_t^{1-\frac{1}{\vartheta P}}$$

Under the assumptions made on price formation in the public service sector, and on the assumption that foreign prices are stationary one can rewrite this equation as

$$PP_tCP_t = \Lambda_t^{e-\frac{1}{\vartheta P}} S_tG_t,$$

where G_t is stationary.

Thus

$$\frac{PP_tCP_t}{PN_tCN_t} = G_t\Lambda_t^{e1-\frac{1}{\vartheta P}}.$$

Then assuming that Λ_t^e grows at a negative rate is sufficient to have a vanishing share for the expenditures on public services.

Consequently if the above conditions are fulfilled, the CPI volatility stemming from public service and food prices decreases as income and consumption grow. Thus even if these prices are more volatile than durable and nontradable prices the volatility of the overall index tends to approach the volatility of the latter two as the economy becomes rich.

4.2 Stabilization of the price level

In our model, irrespective of the price flexibility assumption, exchange rate policy can achieve the stabilization of any individual price index, except for the public service price. A brief inspection of the price formulas shows that all other prices depend on the nominal exchange rate, thus if we allow monetary policy to have the power to respond to shocks simultaneously then any CPI aggregate can be stabilized by appropriately adjusting the exchange rate (i.e. by applying monetary policy in a way that results in an exchange rate in the flexible regime that achieves the stability of the desired price aggregate.) However, flexible exchange rates may have real effects in the model. In the following we will study this issue. We carry out thought experiments: let us suppose that monetary policy is formulated in a way that it responds in a price level stabilizing manner to each of the five shocks. What are the real consequences of, and the possible trade-offs consequent upon these policies? First we must ask what a price stabilizing response means.

Initially let us suppose that aggregate demand policies of the government are given. Inspecting the formulas demonstrates that for the export and import price, and for the productivity variable an increase would lead to a price level increase if the exchange rate were fixed. Thus a strengthening of the exchange rate would be stabilizing in these cases. On the other hand a positive food production shock would result in a reduction in the price level, causing depreciation to be the appropriate response. The foreign interest rate does not figure in anyone of the formulas, thus changes in it should not draw a response from monetary policy. However, it is clear from the implementability condition that aggregate demand policies are affected by foreign interest rate changes, thus foreign interest rates may have an indirect effect on prices. Thus we have to ask what this indirect effect is like.

The implementation condition

$$\Lambda_t^e = \beta I_t^* E_t(\Lambda_{t+1}^e)$$

has one certain implication. Expected aggregate demand must depend on the current foreign interest rate. The aggregate demand expectation has a role in the determination of several prices. It plays a role in the rental price equation, irrespective of price rigidity, and, in the case of rigid prices, influences tradable and nontradable prices as well. The loglinear approximations show, however, that only in the case of the rental price does $E_t(\Lambda_{t+1}^e)$ have a direct effect on the current price. Otherwise only covariance terms, involving surprises are involved in the formulas. In the case of the rental price a decrease in $E_t(\Lambda_{t+1}^e)$, i.e. an expected increase in future aggregate demand, decreases current demand via a negative effect on the rental price. (This is just the effect of increasing the nominal interest rate on the demand for a capital (durable) good.) However, what is important for us here is the response of fiscal policy to a shock to foreign interest rates. We think of aggregate demand policies as substituting for capital markets to stabilize debt in the economy in question. Thus for an indebted country the worsening of borrowing terms would naturally imply a restriction in demand. In other words it is plausible to assume that a current shock to foreign rates results in a higher Λ_t^e simultaneously. It is easy to check that this response entails a reduction in all of the components of the CPI aggregate, except for public service prices, whereupon it has no effect. One can conclude that, because of these indirect effects, the appropriate price stabilizing response of monetary policy would be to depreciate the nominal exchange rate following an increase in the foreign interest rate.

Now it is time to discard the assumption of constant fiscal policy in the face of shocks. One must ask what the fiscal policy responses to the other four shocks are to be, if fiscal policy is supposed to behave in the manner hypothesized. The answers are plausible enough. Food supply shocks should leave aggregate demand undisturbed. Import price increases could invoke tightening, whereas export price and productivity increases would require more relaxed demand conditions. Thus we can summarize how a policy mix that wishes to stabilize prices via monetary policy, and stabilize debt via fiscal policy would look like. Positive shocks to

- productivity and export prices imply monetary tightening and fiscal ease
- import prices imply tightening on both fronts
-food supply imply monetary easing and no fiscal response
-foreign interest rates imply tightening fiscal policy and, as a response to this, loosening monetary policy.

Table 1

	debt stabilizing fiscal	price stabilizing monetary
productivity shock	ease	tighten
export price shock	ease	tighten
import price shock	tighten	tighten
food supply shock	neither	ease
foreign rates shock	tighten	ease

In the case of import price shocks it may happen that fiscal tightening would achieve price stability without the intervention of monetary policy, or even to overshoot so that price stability would require monetary easing.[4] One can see that the conjunction of debt and price stabilization does not in general lead to parallelism. It is only the case of the import price shock when the two policies move parallely.

We have summarized how price stabilizing monetary policies would work. Next we ask whether there are trade-offs, i.e. whether there exist negative side effects to such policies that may prevent their application. First suppose that a negative food supply shock hits the economy, and the exchange rate appreciates to restore price stability. Let us look for effects on tradable and import demand. Appreciation has a negative effect on the demand for public services, because of its predetermined nature. Via this it generates a decrease in the demand for

[4]It is worth noticing that the interplay between responses to these shocks determine the risk premia that are present in three places in the model: the determination of the domestic interest rate, of rigid home tradable prices, and of rental prices.

tradables. With flexible prices no further effect exists, but with predetermined prices there is a reduction in the demand for nontradables and durables, alike. Thus price stabilization would lead to an improvement in the current account, except for a change in the relative prices home producers are facing. Because of price rigidity relative prices are changed, and imports become relatively cheaper than home tradables. The sign of the effect on the current account depends on the precise configuration of parameters. It is important to note that the effect on the demand for durable expenditures is variable, since it depends on the existing stock, thus on the history of shocks and responses. Whatever the net effect is, it remains true that the current account would vary for no good reason at all.

Similar remarks are valid for the other cases as well. Take the example of a positive import price shock. From a debt stabilizing point of view, an adjustment via import substitution would be needed. However, the strengthening of the exchange rate, as a price stabilizing response, makes imports cheaper, thus, as a first order effect, further deteriorates the current account. Of course the effects on total demand may make up for this, but this is a point where one could not make any judgments without knowing the parameters. The main point is that whereas changes in aggregate demand can unambiguously take the current account in the desired direction, monetary policy changes may not. In other words monetary policy as a tool for managing the current account is just a second best solution, and, even for that, price stabilization can have current account effects that may vary in time.

What happens if the exchange rate is fixed? In our model all relative price changes would reflect real variation in exogenous conditions and in fiscal policy. Here price rigidity coterminous with nominal volatility, thus from a real allocation point of view the fixed exchange rate solution seems to be superior. However, if price stability is also desirable, there is a genuine trade-off, the study of which would require the modelling of the costs of price level instability.

To summarize we may state that for avoiding fortuitous changes implied by using monetary policy to stabilize prices, one may resign to accept fluctuating prices. Striving for price stability would result in variation in domestic demand and in the current account in ways that depend on deep parameters, are time-varying, and may have possibly no connection to the debt stabilization objectives. Of course, one can assign a task to fiscal policy to determine its course by taking into account of monetary policy's price stabilizing intentions. Still fiscal policy may be less capable of adjusting, and, at any rate, it is limited by the implementability constraint. In sum, relative price variation may be a concern to policy makers, and in certain circumstances could make them prefer some price level volatility.

4.3 Real interest rates

In the absence of a linear homogenous price aggregate we have to avail ourselves with defining own real interest rates for each good. The own interest rate of some good between t and $t+1$ is the price of the good delivered in t in terms of the same good delivered in $t+1$ minus 1. Then the own expected rate of interest of any good with price P_t can be written as

$$r_{t,t+1} = \frac{I_t P_t}{E_t(P_{t+1})}$$

Assuming that a second-order approximation is valid, the effect of the real exchange rate on the slope of consumption can be written as

$$\begin{aligned} E_t(c_{t+1} - c_t) &= \frac{1}{\vartheta}(i_t - (E_t(p_{t+1}) - p_t) + \log(\beta) + \frac{1}{2}var_t(c_{t+1}) \\ &\quad - \frac{1}{2}var_t(p_{t+1}) + cov_t(c_{t+1}, p_{t+1})). \end{aligned}$$

One can see that the slope depends on the parameter ϑ, higher values of which imply a weaker effect on the expected change in consumption.

For any CPI aggregate we can have a corresponding real interest rate measure, whose interpretation is, however, not clear at all. To get informed on this issue we first ask what the meaning of an interest rate change in our model is. Using again the same approximation we get

$$i_t = i_t^* - s_t + E_t s_{t+1} - \frac{1}{2}var_t(s_{t+1}) + cov_t(s_{t+1}, \lambda_{t+1}^e)$$

Assuming that the expectation terms are constant there is a one-to-one relationship between the nominal exchange rate and the nominal interest rate. An appreciation implies an increase in the interest rate, ceteris paribus, immediately. Thus the real effects of changing the nominal interest rates are those of unexpected nominal exchange rate changes. We next ask whether these changes are associated with changes in the own real interest rates, and what the correlations between real interest rates, prices and demand are.

It is clear that for foodstuffs no changes in the interest rate have any independent effect on consumption. Own rates are independent of the level of the nominal exchange rate, thus no effect via an interest rate-demand-prices channel can exist. For instance food prices can be stable while the exchange rate and the nominal interest rate fluctuate, resulting in real interest rate variation that has nothing to do with demand or price variation. For the other goods price rigidity gives rise to real interest rate effects by altering demand. As public service prices are predetermined, a surprise appreciation gives rise to both an increase in the own real rate, and to a temporary decrease in demand. However, as the demand change depends on the ϑ_P (intertemporal elasticity of substitution) parameter, and the change may be rather small. Still, we have here a negative correlation between the real rate and demand. Suppose now that we have a monetary policy that strives to only partially undoing any price shock. For concreteness' sake, let us assume that the price level is always set halfway between its no shock value and what the shock would imply if exchange rates were fixed. It is clear that this policy would imply a positive correlation between real interest rates and inflation.

For the nontradable demand a negative relationship exists in the case of price rigidity, but its strength depends on the degree of implied price rigidity, and also on the preference parameter, ϑ^N. The situation is the most complicated for the rental price. Price rigidity causes a negative correlation between the real rate and demand, but the relationship depends on the amount of stocks, thus it is time varying. What is also important here is that the relevant price for demand determination is the rental prices, and not the price of the tradable-durable good. Indeed one can see from the relevant formulas that the effect of price rigidity has two effects on the rental price, thus the change in the nominal exchange rate can be magnified. Again an important conclusion is that the same real rate have probably time varying effects, depending on the state of the economy.

Does a change in demand influence prices present or future? One way how current monetary policy may affect future prices can be its effect on the future course of fiscal policy, the Λ^e_{t+1} variable. If we assume that fiscal policy is debt consciousthen a current exchange rate change that increases (decreases) foreign debt leads to an expected increase (decrease) in Λ^e_{t+1}, and thereby, a downward (upward) pressure on tomorrow's price level. However, this pressure depends on the net effect on imports of exchange rate policy, whose sign is *a priori* uncertain, and time varying.[5]

From the above analysis we have the following general observation about real rates in this economy: with exchange rate flexibility it is possible to obtain a fixed price level, by changing nominal and, therefore, real interest rates, thus, though the real rates and demand are negatively correlated, prices and real interest rates are not correlated at all.

A few important conclusion emerge from the above discussion.

- If we want a measure of the real interest rate that can be a useful indicator supply determined prices should not be part of the corresponding price index.

- As the demand effects of interest rates depend on intertemporal substitutability, any aggregate index unaware of this can be misleading to infer the influence on demand from.

- Because of the existence of durables the effect of the interest rate on demand must be time varying.

- A strong positive correlation between prices and real interest rates may signal only partial commitment to price stability.

4.4 Core inflation

Even the very term core inflation reflects the desire of many to capture an inherent and presumably essential feature of reported inflation indices. By core inflation different authors refer to things that have similar, but not identical,

[5] Maybe this uncertainty is the cause of a certain schizophreny exhibited by central bankers. They sometimes wish a weaker exchange rate and a higher interest rate simultaneously.

properties. (For a survey see Wynne [1999].) Supporters of one view claim that core inflation is a price index over which monetary policy exerts (direct) influence. On another view it is something which contains small temporary noise. In fact, the accurate definition of both criteria would require some model in order to reveal if they are identical or what differences they have. If an optimal core inflation measure is sought for, one cannot ignore the question of what kind of information one intends to distil from it. Now we will consider the consequences of defining core inflation indexes in our model. Roughly our concern is to speculate on what sort of information a specific core index may provide or hide. Of the known domain of methodologies we will look at two general classes: core inflation obtained by excluding certain subgroups, and by excluding outliers.

4.4.1 Excluding certain subgroups

In order to define a core inflation index a frequent expediency is to exclude food (or at least certain food) prices from the CPI . In our model, quite naturally, food prices contain information not only on supply shocks, but on demand and monetary policies as well. Thus excluding food prices may prevent one from judgeing whether monetary policy has in mind the stabilization of the price level. However, our model also suggests that responding to supply shocks may have unwanted side effects, via generating relative price and domestic demand variation. If this is thought to be a nuisance then monetary policy has a reason to neglect food supply shocks. This is a decision based on a judgment concerning the trade-off between the adverse effects of price level instability and real instability. The decision taken in this matter can tell us something about monetary policy.[6]

Another usual expediency is to exclude public sector prices or changes in indirect taxes, where the latter is somewhat similar to the former in the framework of our model. There is a certain plausibility to the idea that these prices may provide useful information on future monetary policy, and inflation, as long as their pricing is motivated by price expectations. (See Cecchetti-Groshen [2000].) However, in the practice of transition economies the monthly variation of public service prices has been high, as noted above. Political considerations caused another type of uncertainty: though adjustment have been made usually once a year, this adjustment was not realized in every year. Thus in the catch-up period the potentially useful information provided by these prices may have been substantially noisy.

Excluding durable prices has probably never been considered. Still there is a sense in which this could be useful: this would be the case if in certain circumstances durable prices were a very noisy signal of true rental prices.[7] In principle rental prices have useful information on policy since they inform on expectations. Of course it is an important empirical problem whether the

[6] Of course the size of shocks can be an influential motive to neglect these shocks, too.

[7] If durable prices are included because they are related to transactions demand for money then it is not clear why house or share prices are not included in the price index to be watched or stabilized.

supply of durables is capable of adjusting promptly to shocks. In our model this is assumed, but on some real markets, this may be far from the truth. In this case rental prices may be similar to food prices.

Excluding nontradable prices has not been considered, either. In our model they are probably the most synthetic variable that contain information on many aspects of the economy. For this reason this information may not be particular to monetary policy. Thus demand and tax policies may have substantial roles in determining nontradable prices in the short run. On the other hand technological shocks may have permanent effects on them, making them less than perfect for signalling the stance of monetary policy.

In sum one can have arguments for and against excluding from the CPI the usual candidates. On the other hand, one can even have reasons to exclude those subgroups that are normally considered to belong to the core. Concrete circumstances and purposes are decisive.

4.4.2 Excluding outliers

Trimming is haloed as a method to filter out temporary noise, without the need to decide beforehand from what source this noise may originate. However, it has been argued that trimming may discard very good information if certain price makers set prices according to expectations. (See Bakshi-Yates [1998].) This may be a reason why infrequently changed public service prices should not be excluded at the time when they are changed, even if they seem to be outliers at that moment. An important aspect of our model is that a price stabilizing monetary policy narrows the spread between predetermined public service prices and those that are at least partially responsive to exchange rate shocks immediately. In this sense if policy is required to actively stabilize the price level, then large spreads of the distribution may signal that policy is not up to this task. On the other hand, the relative price of foodstuffs in terms of, say, nontradables can be either larger or smaller, depending on the exact state of shocks. Thus we must know more about the nature of relative price changes than simply attributing it to noise. Indeed it seems somewhat incredible to claim that central banks cannot do anything with food or energy prices (see this claim for instance in Blinder [1997]) that may be outliers more frequently than others. Still, as we have seen, central banks might have reasons to do little about these prices. This is, however, a signal of preferences, and not of feasibility.

4.4.3 Discussion

Thus we conclude that if one wants to make sense of any adjustment to the price index, or in general, to define an appropriate price index, one must be very specific about the structure of the economy, and of what is expected of monetary policy. We believe that core indexes make sense as long as they have a useful function for policy makers or analysts, and not because they grasp some fundamental feature of never changing reality. Thus the concept of core inflation cannot be seen as either a purely statistical phenomenon or a universal problem that is free of national characteristics. Let us look at a few practical examples.

1. Temporary changes in (non-processed) food supplies. A monetary policy response to such changes may cause large relative price fluctuations, and unwarranted real volatility. Therefore, for a central bank caring about this, the right core inflation index seems to be such that excludes these prices. At the same time, the operation of food markets may vary from country to country. While in some countries such supply shocks occur frequently and tend to cause significant changes in the CPI, in other countries they are supposed to be of no consequence. If the latter is the case there is no reason to meddle with the price index on their account.

2. Changes in taxation. The issue to resolve here is how persistent the effects on inflation of a specific tax change will be given the reaction of markets. Also, whether the real distortion caused by the tax change is of a type that will prompt monetary policy makers to take corrective action on the basis of their preferences and views on the operation of the economy. For example, an increase in labor costs is likely to speed up inflation, and not only in the very short run. An inflation-wary monetary policy maker will conclude from this that tightening may be in order. However, tightening may further aggravate the probably ensuing direct drop in profitability and take the economy towards recession. This is no trivial problem for a monetary policy maker seeking to achieve real economy objectives as well. Easing is another alternative, but the monetary policy maker may also decide not to make moves in either direction. If the latter is the case the effect of the tax change may be excluded from the core inflation index.

3. Fuel price changes. Experience has shown that changes in oil prices tend to be persistent, lacking, however, a permanent positive or negative trend. Central bankers may be faced with the genuine dilemma whether to treat oil price changes the same way as changes in non-processed food prices or to take them seriously instead. The outcome of their pondering obviously depends on the exposure to fuel prices of a country's price level. Another criterion of decision making may be whether monetary policy makers wish to correct the changes in the terms of trade and in the real exchange rate that follow.

We would like to conclude by adding two further practical comments. First, in view of the fact that monetary policy objectives and the structure of the economy may change over time, a correct core inflation index, as well as the weights given to the individual components, may also undergo a simultaneous change. Second, the relevance or irrelevance of a particular price shock to core inflation does not depend on whether the shock is temporary or not. The appropriate propagating mechanisms might make the most ephemeral shock persistent and even relevant.

5 Conclusions

In this paper we investigated the consequences of introducing goods heterogeneity into a stochastic general equilibrium model of a small open economy. Looking at the behavior of individual price series suggests that such an approach is required to answer certain questions. The main body of the study contains a model that serves for clarifying ideas, and also for enabling us to derive the consequences of some hypotheses. For the sake of treatability we had to make several simplifying assumptions, the most heroic being that regarding fiscal policy. In essence it is assumed that fiscal policy controls aggregate demand (under an implementability condition) via determining the euro marginal utility of households. What are the most likely shortcomings of the model with a possible influence on the inferences we drawn?

Excluding money and money demand from models used for the analysis of monetary policy has been in vogue for some time. This certainly makes an already complicated mathematical system more amenable to analysis. It is not clear, however, that this may not be misleading. One can give a justification for this neglect of money if one had money-in-the-utility function cum separability assumptions. We see little reason to include such a money demand formulation in the model. However, some more plausible specification may bring important changes and new conclusions into the analysis, and it would be worth trying. This, however, would also necessitate a numerical approach, towards which we want to move anyway.

Our modelling of fiscal policy may raise questions of consistency. Numerical solution of the model may also be useful in checking whether treating Λ_t^e as a (constrained) policy variable is consistent in the sense that one can establish a mapping between this variable and more traditional or fundamental fiscal policy variables.

The present model may contain some features that depend on the modelling of price setting. Clearly there are too few nominal and real rigidities in the model, and all inflation inertia must be attributed to (unexplained) policy inertia. Also too many of the results may be driven by the assumption of foreign currency pricing of both exports and imports, which, however, does not seem to be a totally implausible assumption for small developing economies.

The decomposition of the aggregate CPI as modelled here only partially answers the empirical description reported in Section 2. To make the model more useful for understanding the past, and, possibly, for forecasting the future, it may be necessary to add new goods, like energy or commodities, as well as to relax the simplifying assumptions concerning the food sector. This step towards enhanced realism would also lead us to numerical simulations.

Having said that we can summarize the most important lessons of this study which may survive future refinements of the model.

First, it seems justified that the conjunction of nonhomothetic preferences and permanent relative price changes raises the possibility that some of those notions we mentioned in the Introduction should be modified. With respect to price stability we found that at higher income levels for any given monetary policy rule CPI volatility probably gets lower, and that monetary policies striving for stabilizing prices may involve fortuitous changes in real variables. (This result can be contrasted with the finding that stabilizing prices is optimal in models with essentially homogenous goods, but differential costs to changing prices.) Concerning real interest rate indicators we can conclude that they must be calculated with a careful view towards differential intertemporal substitutability if they are to make any sense at all, but still they may not have the assumed correlation with inflation. Regarding the use of core inflation indexes it has to be pointed out that goods heterogeneity may require other types of considerations that have been developed in the literature.

Second, we were able to derive some interesting hypotheses about price formation, such as those referring to risk premium terms that may give rise to relative price changes distinct from those stipulated by Balassa- Samuelson-type theories. And it turned out that the monetary-fiscal policy mix can modify durable prices, for instance parallelism (as defined above) may cause them to increase.

Third, we obtained assertions about policy. We found that parallelism is not consistent with price stability except when import price shocks are the overwhelming source of fluctuations. Also trade-offs between price level stability and real stability may exist, and stabilizing the price level may have uncertain effects on the current account. Furthermore because of the existence of durables, or capital goods in general, the effect of monetary policy on demand must be time varying. Finally it appears that a strong positive correlation between prices and real interest rates may possibly signal only partial commitment to price stability.

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