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Vadims Sarajevs

Money Shocks in a Small Open Economy with Dollarization, Factor Price Rigidities, and Nontradeables

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Vadims Sarajevs*

Money Shocks in a Small Open Economy with Dollarization, Factor Price Rigidities, and Nontradeables

Abstract

The impact of an unanticipated monetary shock in a small open economy with dollarization, factor price rigidities, and nontradeables is re-examined in an optimizing intertemporal general equilibrium model. The framework of an earlier study is extended to incorporate foreign real money balances into the representative agent's utility function and to account for the phenomenon of dollarization so characteristic of transition economies. The major finding is that in the event of small monetary shocks, the presence of dollarization does not alter the outcome that relates the sign of response of consumption, current account balance, and other macroeconomic variables to the difference between *inter*temporal and *intra*temporal elasticities of substitutions of the total consumption index. The solution also shows that the elasticity of intertemporal substitution of money services and the share of traded goods in total consumption – a proxy for openness of the economy – are the crucial parameters in determining the response and the possibility of overshooting of the model variables, with economic openness playing a stabilizing role for the economy in the event of monetary shocks.

Keywords: New open-economy macroeconomics; Monetary shocks; Dollarization; Factor price rigidities; Nontradeables; Current Account

JEL classification: F31; F32; F41, F47

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Introduction

This paper re-visits the impact of an unanticipated monetary shock in a small open economy with dollarization, factor price rigidities, and nontradeables. The unique feature of this paper is the introduction of foreign real money balances into a representative agent utility function. The motivation behind this extension is to orient the recent "new open economy macroeconomics" research trend closer to the transition economies environment.

Prominent features of the "new open economy macroeconomics" literature are proving to be very relevant to the ongoing research on transition economies[1]. This literature re-vitalizes the traditional open economy macroeconomics with the introduction into the dynamic general equilibrium intertemporal approach of two generally omitted components: nominal rigidities and market imperfections. The presence of nominal rigidities allows for non-neutral, non-trivial monetary policy effects, while the presence of market imperfections – normally monopolistic competition – allows for non-trivial pricing decisions and makes the output demand-determined in the short run. Nominal rigidities come into the model through the pre-set wages[2].

Generally, one would anticipate an important role for nominal rigidities in economic transition from the centrally planned to the market economy. The gradual and asynchronous liberalization of prices in different sectors of the economy constitutes the main reason for this expectation. It is reinforced by even slower liberalization of labour market relationships, which are persistent and difficult to change. As a result, the flexibility of the labour market lags behind that of the goods market, making wages more rigid than the prices of goods, thus justifying the choice of wage over price rigidities.

The second crucial feature for correct macromodelling of transition economies is the existence of market imperfections, which are reflected by monopolistic competition in labour and goods markets. It is a stylized fact that the former centrally planned economies were characterized by a very high degree of concentration in industry. Often only one or two enterprises were engaged in the production of a particular good. As economic reforms

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[1] This concept emerged in the second half of the 1990s, with a major contribution from Obstfeld and Rogoff (1995, 1996, 1998, 2000). Since 1995, additional authors have contributed to the concept's study. For an extensive survey, see Lane (1999b).

[2] A review of nominal rigidity's theoretical and empirical developments is presented in Taylor (1998).

were initiated the problem of monopoly was tackled from two sides. On one side, the process of privatization was launched, which often included the option for break-up of large monopolies. On the other side, an appearance of a new economic sector of private businesses was expected to create a more competitive environment. However, although these two forced are at work, one needs to acknowledge the following. First, privatization often progresses through a number of stages over a long period of time. Hence, enormous monopolies that are typical of centrally planned economies continue to exist for long periods of time following the institution of reforms and remain capable of exercising a large degree of monopoly power. Second, new market participants and infrastructure develop over time, tending to be small in quantitative terms and weak in generating enough market power to create a competitive environment. Further, the new sector growth starts first in services and only later in manufacturing. Finally, often the incentives behind the decision to open a new business are not to fight a monopoly, but exactly the opposite: to be first in that particular market niche to collect monopolistic profits before other businesses move in, create a competitive environment, and drive the monopolistic level of profit down to the normal level, which, of course, only happens over a considerable length of time. Therefore, we believe that a monopoly assumption is a good conjecture and represents a significant feature of transition economies.

Finally, the necessity to model transition economies as open economies must be stressed. Some of the major developments taking place in transition economies are related to a swift lifting of restrictions on foreign trade, the export and import by non-governmental market participants, and the liberalization of foreign exchange markets. These actions have contributed to a sharp rise in mutual trade between Central and Eastern European transition economies and the European Union (EU), resulting in the increased integration of goods and capital markets and strengthening the prospects of an eventual EU accession for a majority of these countries. Therefore, it is important to have a workable theoretical framework that treats transition economies not as closed and isolated, but as small open economies. The reference to “small open economies” is used because each of the 13 transition economies in Central and Eastern Europe and the Baltic states[3] is relatively

[3] These countries are: Albania, Bulgaria, Croatia, Czech Republic, Estonia, FYR Macedonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, and Slovenia. Among these countries, Poland had

small in economic terms when compared to the EU (their major economic partner) and to the EU's largest members (e.g., Germany, France, and Britain).

The economic features described in the previous paragraphs justify the use of a modern theoretical approach as developed by the "new open economy macroeconomics" literature. However, the approach should be modified to account for one other specific feature of transition economies, the widespread and persistent phenomenon of dollarization or currency substitution[4]. This phenomenon manifests itself when the foreign currency performs traditional functions of domestic money as store of value, unit of account, and medium of exchange. When the environment of transition is uncertain due to changing property rights, political instability, large budget deficits, and high inflation, foreign currency may take on all or at least some of the function of domestic money to hedge economic agents from these adversities. The levels of foreign real money balances in transition economies often declined after successful stabilization, but due to hysteresis effects and habit persistence, rarely fell to negligible levels. Therefore, we would like to account for this phenomenon and to investigate the following question: Does the presence of dollarization alter in any significant way the major conclusions derived from "new open economy macroeconomics" research, with respect to the effects of an unanticipated monetary shock in a small open economy?

The following section presents the model of small open economy with dollarization, factor price rigidities, and nontradeables, and derives the first order conditions. *The Flexible Price Symmetric Equilibrium* section solves the model for the specified equilibrium. It is followed by the section *The Log-Linearized Model Solution for an Unanticipated Money Shock*. We conclude and comment on future research in the last section. Finally, all details of derivations, figures, and tables are collected in Appendices.

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the largest GDP in 1998 – USD 150 billion. For comparison, the United Kingdom's GDP in 1998 was USD 1,406 billion. See Table 3 for more details.

[4] Major surveys on the problem of dollarization/currency substitution are presented by Calvo and Vegh (1992) for developing countries; Savastano, M. A. (1992 and 1996) provides similar insightful studies on Latin America; recent surveys of theoretical and empirical problems and developments in the field include an excellent paper by Giovannini, A. and B. Turtelboom (1994) and the broad-scoped book by Mizen, P. and E. J. Pentecost (1996); and Sahay and Vegh (1995) survey the problem for transition economies. One of the first empirical studies of currency substitution in transition economies, the case of Latvia, is presented in Sarajevs (2000).

The Model

We consider a small open economy as one that behaves as a price-taker in trade for tradeables and takes all foreign variables as exogenously given. In the spirit of work by Obstfeld and Rogoff (1996, Ch. 10.4), Obstfeld and Rogoff (2000), and Hau (2000), we assume that nontraded sector firms produce differentiated goods out of differentiated labour inputs, with both represented by corresponding indices over the unit interval *[0,1]*. The traded sector produces a homogeneous traded good competitively at an exogenously given level of output. In this asymmetric set-up for traded and nontraded sectors, we follow Lane (1999a). There is a number of reasons behind this choice. First, we wish to emphasize the notion that in a small open economy, domestic aggregate demand conditions have a greater significance for the nontraded sector output than for the traded one. During the reforms the economic conditions in the domestic economy are more dynamic and are changing faster than the demand by the rest of the world for the domestically produced traded good. In the short- to medium-run the traded sector, being a world price-taker, is affected by the domestic conditions to a much lesser degree that the nontraded sector. Hence, our assumption of an endowment character of the traded sector is rather innocuous and brings a great deal of simplification for the solution procedure. This also means that the domestic money shock impacts on the nontraded sector first. Later, the effects of the shock are transmitted to the traded sector through the changes in the composition of the total consumption, which consists of traded and nontraded goods components. Two sources of monopoly are represented in the model. First, the households behave monopolistically in their decisions on labour supply. Each household worker is represented by a point on the unit interval and is a monopolistic supplier of specialized labour services to the nontraded sector. Second, each of the continuum of firms in the nontraded sector behaves monopolistically in its choice of optimal product prices. In addition, we assume the presence of nominal wage rigidities, with nominal wages preset for one period in advance[5]. The prices of all goods are fully flexible.

[5] Obstfeld and Rogoff (2000, p. 129) argue in favour of the nominal wage rigidity assumption over an alternative output price rigidity, as the former is a closer approximation to reality. However, in their research, Obstfeld and Rogoff (1996, Ch. 10) show that both types of models, sticky-wage and sticky-price models, deliver very similar results to the effects of a money shock on the exchange rate, nontraded goods prices, and welfare.

In the model description that follows, a convention of time-dependent variables will be observed. Time dependent variables will be denoted with a subscript “t.” When discussing a variable in general, or when referring to the steady state of a variable, the subscript “t” will be dropped.

Households

The utility function of an individual household *j* will assume the typical form presented in “new open economy macroeconomics” literature,

Equation 1 Utility Function

$$U^j = \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(\Omega_t^j\right)^{1-\rho}}{1-\rho} + \frac{\chi}{1-\varepsilon}\left(MS_t^j\right)^{1-\varepsilon} - \frac{k}{v}\left(L_t^j\right)^{v} \right],$$

where ρ, ε, and $k > 0$, $v \geq 1$. The total consumption index, Ω, aggregates consumption of traded and nontraded goods in the CES (Constant-Elasticity-of-Substitution) form,

Equation 2 Total Consumption Index

$$\Omega = \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}},$$

where $\theta>0$ is the constant elasticity of substitution between traded and nontraded goods at any moment in time, i.e. *intra*temporal substitution. The utility of total consumption is of an isoelastic type, with the elasticity of substitution between consumption at any two points in time (i.e. *inter*temporal substitution) being constant and equal to ($1/\rho$). In the presence of uncertainty, this type of utility function is also called the CRRA (Constant Relative Risk Aversion) utility, with the coefficient of relative risk aversion being equal to ρ. The second term of Equation 1 represents the utility derived from money services, which are provided by the holdings of real money balances of domestic and foreign currency and facilitate transactions. The third term reflects the disutility of labour efforts.

It is assumed that period utility is separable in labour efforts and money services. Indeed, separability in labour efforts is present in the overwhelming majority of research on new open-economy macroeconomics. Under this assumption, the growth rate of consumption does not depend on the growth rate of real wages (see Obstfeld and Rogoff [1996, pp. 114-116]); hence, investment decisions can be separated from consumption decisions, which would not, in general, be the case otherwise. For our purposes, this does not represent a serious obstacle, as we are not so concerned with long-run capital investment decisions, but rather, with the short- to medium-term effects of monetary shocks. The second assumption on the separability of utility in money services is harder to justify, however. This assumption supports that money holdings do not directly affect marginal rates of intertemporal substitution of consumption. Nevertheless, money holdings can affect the paths of consumption and current account balance through the path of prices. A major argument for sticking to the assumption of money services separability is the desire to maintain some level of analytical tractability of the models[6].

Money services are given by

Equation 3 Money Services

$$MS_t = \frac{M_t}{P_t} + g\left(\frac{P_{T,t} \cdot M_t^*}{P_t}\right),$$

where M_t^* is the nominal amount of foreign currency. The g function for foreign real balances holdings has an exponential form. This kind of function is also called a CARA (Constant Absolute Risk Aversion) function, with α being the coefficient of absolute risk aversion.

[6] While new open-economy macroeconomics literature is vast, to our knowledge, only papers by Chari, Kehoe, and McGrattan (1998) and Kollmann (1997) employ nonseparable in the money services utility structure. This, of course, leads to the necessity of numeric simulation study of the model's solutions.

Equation 4 Utility of Foreign Balances

$$g\left(\frac{P_{T,t}\cdot M_t^*}{P_t}\right)=\frac{1}{\alpha}\left[1-\exp\left(-\frac{\alpha\cdot P_{T,t}\cdot M_t^*}{P_t}\right)\right],\quad \alpha>0$$

The choice of functional forms is arbitrary to a large extent. In choosing this particular functional form for the utility of foreign balances, we were guided by the Obstfeld and Rogoff (1996, pp. 551-553) treatment of the dollarization phenomenon. Specifically, Obstfeld and Rogoff propose a simple quadratic function in real foreign money balances to approximate the dollarization phenomenon, rationalizing it by the presence of evasion costs and high inflation rates typical for many developing countries. Our choice of an exponential utility is consistent with the Obstfeld and Rogoff approximation and restrictions on coefficients if we perform a Taylor series expansion and keep the terms of up to the second order only. In addition, our choice has the advantage of not being an approximation, but a full analytically convenient exponential function.

It is assumed that with no impediments to trade, the PPP (Purchasing Power Parity) holds for tradeables

$$P_T=E\cdot P_T^*$$

We normalize foreign tradeables price to unity, hence

$P_T=E$.

The domestic price of tradeables will serve as nominal exchange rate as well.

We assume that there is only one internationally traded asset: a riskless real bond denominated in tradeables, B_t. It pays off an exogenously given real return r, where we set $\beta(1+r)=1$ to have constant consumption in a steady state. The typical flow budget constraint for household j is given by

Equation 5 Household Budget Constraint

$$P_{Tt}B_{t+1}^j+M_t^j+P_{Tt}M_t^{*j}=P_{Tt}(1+r)B_t^j+M_{t-1}^j+P_{Tt}M_{t-1}^{*j}+w_t^jL_t^j+P_{Tt}\bar{y}_T-P_t\Omega_t^j-P_t\tau_t$$

The right hand side gives the available resources as the sum of gross return on the bond holding, initial money holdings, labour income, constant endowments in tradeables, less total consumption and government taxation. These resources are used to acquire the next period money balances and new bond holdings. Notice that M_t denotes the quantity of nominal money balances acquired during period t and carried over into period t+1.

The total consumption-based price index is defined as the minimum expenditure necessary to buy one unit of the total consumption index Ω, and is given by (see Appendix *The total consumption-based price index* for derivation)

Equation 6 Total Consumption-Based Price Index

$$P = \left[\gamma P_T^{1-\theta} + (1-\gamma) P_N^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

By introducing the total consumption-based price index in this way we allow ourselves to work entirely with the total consumption index Ω only, instead of both of its components (C_T, C_N), which can always be recovered through Equation 32 if necessary.

There is a continuum of nontraded goods indexed by z on the unit interval, $[0,1]$. The real consumption index of nontraded goods is given by a natural generalization of the two-good CES function

Equation 7 Real Consumption Index of Nontraded Goods

$$C_N = \left[\int_0^1 c_N(z)^{\frac{\phi-1}{\phi}} dz\right]^{\frac{\phi}{\phi-1}}, \quad \phi > 1$$

The corresponding consumption-based price index for nontraded goods is given by (see Appendix *The consumption-based price index for nontraded goods* for definitions and derivations)

Equation 8 Price Index for Nontraded Goods

$$P_N = \left[\int_0^1 p_N(z)^{1-\phi}\,dz\right]^{\frac{1}{1-\phi}}$$

Given the CES form of the real consumption index of nontraded goods, it is possible to derive an individual's demand schedule for a nontraded good *z*

Equation 9 Demand Curve for Nontraded Good *z*

$$c_N(z) = \left(\frac{p_N(z)}{P_N}\right)^{-\phi} C_N$$

As the aggregate demands in Equation 32, demand for a nontraded good *z* is proportional to an aggregate consumption of nontradeables, with a proportionality coefficient being an isoelastic function of the ratio of the nontraded good's price to the total price index for nontraded goods. An individual firm takes this nontraded good demand schedule into account while performing profit maximization.

Firms

Given that the production level is exogenously fixed in the traded sector, consideration is now given to nontraded sector firms' production technology. It is assumed that firms produce differentiated nontraded goods out of differentiated labour inputs according to a generalized linear-homogeneous CES form production function. Let $Y_{Nt}(z)$ as the output of a differentiated nontraded good *z* by the firm *z*, assuming the same indexation (*z*) for the firm and for the nontraded good, then

Equation 10 Production Function for Nontradeables

$$Y_{Nt}(z) = \left[\int_0^1 L_t^j(z)^{\frac{\varphi-1}{\varphi}} dj \right]^{\frac{\varphi}{\varphi-1}}, \quad \varphi > 1$$

Let w^j be the nominal wage of the household j labour supply. Define the wage index, W, as the minimum cost of producing one unit of output. Then by the full analogy with Equation 7 and Equation 8 we can define the wage index W as

Equation 11 Wage Index

$$W = \left[\int_0^1 \left(w^j \right)^{1-\varphi} dj \right]^{\frac{1}{1-\varphi}}$$

Given firm's production function and wage index we can show (see Appendix *Labour demand function* for derivations) that the firm's cost minimization problem implies that the demand for labour type j by firm z has the following form:

Equation 12 Labour Demand Function

$$L^j(z) = \left(\frac{w^j}{W} \right)^{-\varphi} Y_{Nt}(z)$$

An individual household takes this labour demand schedule into account while performing utility maximization.

We can drop the superscript notation in future references because in a symmetric equilibrium we are going to derive below all households and firms behave identically.

The optimal product prices can be determined as the solution to the firm's profit maximization problem (see Appendix *Optimal product prices* for derivations). While maximizing profit, the monopolistic firm takes into account the consumer demand curve given by Equation 9. The optimal product price is given by the following equation:

Equation 13 Optimal Product Prices

$$P_{Nt} = \frac{\phi}{\phi - 1} W_t$$

Equation 13 shows the traditional monopolistic pricing behaviour, where product price P_N differs from the production cost W by a mark-up factor $\phi/(\phi - 1)$.

First Order Conditions

The first-order conditions for the household utility maximization problem with respect to the household's choice variables: B_{t+1}, M_t, M_t^*, and w_t, subject to the budget constraint of Equation 5, and the labour demand schedule of Equation 12, are given by (see Appendix *Household's first-order conditions* for derivations)

Equation 14 Household's First-Order Conditions

$$\Omega_{t+1}^{-\rho} = \Omega_t^{-\rho} \cdot \frac{P_{Tt}}{P_{Tt+1}} \cdot \frac{P_{t+1}}{P_t}$$

$$\chi \left\{ \frac{M_t}{P_t} + g\left(\frac{P_{Tt} M_t^*}{P_t} \right) \right\}^{-\varepsilon} = \left(1 - \frac{\beta P_{Tt}}{P_{Tt+1}} \right) \Omega_t^{-\rho}$$

$$g' = \exp\left(-\frac{\alpha P_{Tt} M_t^*}{P_t} \right) = \frac{1-\beta}{\left(1 - \frac{\beta P_{Tt}}{P_{Tt+1}} \right)}$$

$$\Omega_t^{-\rho} \frac{w_t}{P_t} = \frac{\varphi}{\varphi - 1} k L_t^{\nu - 1}$$

The first equation is a familiar intertemporal Euler equation for the total consumption index linking the growth rate of consumption to the time paths of prices, i.e. the total consumption-based price index and the price of tradeables. More can be determined on the effect of prices and utility function parameters (see Equation 1 and Equation 2) if we rewrite this equation in disaggregate form. Using tradeables consumption from Equation 32 yields

Equation 15 Euler Equation for Tradeables

$$\frac{C_{T,t+1}}{C_{Tt}} = \left(\frac{P_t}{P_{Tt}} \Big/ \frac{P_{t+1}}{P_{T,t+1}} \right)^{\frac{1}{\rho}-\theta}$$

This shows that tradeables consumption growth depends on the series of relative prices (P/P_T). Specifically, similar to the discussion in Obstfeld and Rogoff (1996, pp. 234-235), the effect of a (P/P_T) fall on tradeables consumption depends on the difference between *inter*temporal and *intra*temporal substitutions, $1/\rho - \theta$. Other things equal a falling (P/P_T) causes C_T to rise with the elasticity $1/\rho$, but by making tradeables comparatively more expensive, it also induces a switch to nontradeables with the elasticity of θ. When two elasticities are equal, the effects cancel each other and the consumption path is independent of prices.

The second equation connecting money services to the total consumption index and the time path of the price of tradeables is a money demand equation, addressed in the next paragraph. The third equation delivers the demand for the real foreign money balances, which responds positively to an increase in the rate of depreciation of the exchange rate $\Delta E \equiv P_{T,t+1}/P_{T,t}$. The fourth and the last equation is the labour-leisure trade-off condition that comes from utility maximization with respect to wages. It ensures that marginal disutility of the additional factor supply (due to leisure foregone) kL^{v-1} on the right hand side is compensated by an extra unit of marginal utility of consumption $\Omega^{-\rho}$, such that an extra unit of labour supply can buy at the real factor price w/P on the left hand side. The disparity between these elements is equal to the mark-up $\varphi/(\varphi-1)$ charged by a household due to monopolistic market power over production inputs.

To demonstrate that demand for real money balances has rather traditional features, substituting the third equation from Equation 14

Household’s First-Order Conditions into the second one is necessary. This yields

Equation 16 Money Demand

$$m_t \equiv \frac{M_t}{P_t} = \left(\frac{\chi}{\left(1 - \frac{\beta P_{Tt}}{P_{Tt+1}}\right)} \right)^{\frac{1}{\varepsilon}} \cdot \Omega_t^{\frac{\rho}{\varepsilon}} + \frac{1-\beta}{\alpha} \cdot \frac{1}{\left(1 - \frac{\beta P_{Tt}}{P_{Tt+1}}\right)} - \frac{1}{\alpha}$$

Equation 16 shows that demand for real money balances increases in the level of the total consumption index and decreases in the nominal interest rate as traditional Keynesian theory asserts. To demonstrate the latter condition, one can derive that $m_t \sim -\Delta E$, where as above $\Delta E \equiv P_{T,t+1}/P_{T,t}$ is the rate of depreciation of the exchange rate, and assume that domestic interest rates are moving in the same direction with ΔE.

Finally, we assume no role for the government here, i.e. the government expenditures are zero, and all seigniorage revenues are rebated to the households in the form of lump-sum transfers

$$\tau_t = -\frac{M_t - M_{t-1}}{P_t}$$

The first-order conditions in Equation 14, the period budget constraint in Equation 5, the transversality condition in Equation 42, the optimal product prices in Equation 13, and the relational equations presented in Equation 6 and Equation 32 completely characterize the equilibrium. This is the system of nonlinear equations, which in general has to be solved numerically for general paths of exogenous variables. However, this can be solved for the special case of symmetric equilibrium with initial zero net foreign assets, $B_0=0$.

The Flexible Price Symmetric Equilibrium

We now turn to the description of a symmetric equilibrium where all prices are flexible and all exogenous variables, including domestic money stock, are constant with an initial level of net foreign assets equal to zero, $B_0=0$. In the symmetric equilibrium, all firms behave identically and all households behave identically, therefore, one can work with a single representative household and a single representative firm. Following the solution procedure outlined in Lane (1999a), we normalized the endowment of a traded good in the steady-state in such a way that $P_T=P_N$. The level of the endowment of a traded good in this case is given by

Equation 17 Traded Good Endowment

$$\bar{y}_T = \frac{\gamma}{1-\gamma} Y_N$$

This follow from the fact that in the steady-state, with zero bond holding $C_N=Y_N$ and $C_T = \bar{y}_T$, the link between C_T and C_N derived from Equation 32 and given below

Equation 18 Tradeables and Nontradeables Consumption Link

$$C_{Tt} = \frac{\gamma}{1-\gamma}\left(\frac{P_{Tt}}{P_{Nt}}\right)^{-\theta} C_{Nt}$$

From Equation 6 and Equation 32 it follows that $P=P_N=P_T$ and $C_N=(1-\gamma)\Omega$, hence, from Equation 13 and the labour-leisure trade-off condition from Equation 14 we obtain the steady-state value of the nontraded goods output

Equation 19 Steady-State Output of Nontraded Goods

$$\bar{Y}_N = (1-\gamma)^{\frac{\rho}{\rho+\nu-1}}\left[\frac{(\varphi-1)(\phi-1)}{\varphi\phi k}\right]^{\frac{1}{\rho+\nu-1}}$$

It deserves a few comments. First, money is neutral in the case of flexible prices and the level of output is independent on monetary factors. Second, it can be seen that more competitive factor and product markets will lead to lower mark-ups and higher output. This is also the case when different non-traded goods and types of labour become close substitutes (correspondingly increasing ϕ and φ) alleviating the monopolistic distortions. Therefore, output is suboptimally low in this kind of decentralized competitive equilibrium, and a central planner could deliver a higher level of output by coordinating the behaviour of monopolistic producers and consumers. The lower weight on the labour efforts[7] (k) increases the output, as does the higher share of nontraded goods ($1-\gamma$) in the total consumption index.

The steady-state demand for the foreign real money balances is zero from Equation 14, where the no-speculative-bubles assumption, $P_{Tt}=P_{T,t+1}$, was employed. Intuitively, if there are no economic incentives to hold foreign currency, i.e. the rate of depreciation of exchange rate is zero, and there are non-zero costs of holding or using foreign currency (e.g. due to foreign exchange market fees or fines for evading government regulations) no rational economic agent will hold foreign currency balances in such a steady-state. Finally, given an initial level of domestic money stock M_0, we can find prices from Equation 14. An initial price level P_0 is given by

Equation 20 Steady-State Price Level

$$P_0 = M_0 \left[\frac{(1-\beta)(1-\gamma)^{\rho}}{\chi} \right]^{\frac{1}{\varepsilon}} \cdot \left(\overline{Y}_N \right)^{-\frac{\rho}{\varepsilon}}$$

Finally, we notice that the steady-state real interest rate is constant and given by $r=(1-\beta)/\beta$.

[7] This is equivalent to an increase in productivity effect.

The Log-Linearized Model Solution for an Unanticipated Money Shock

To gain some intuition and insight into the model's internal mechanics, we first log-linearized the model around the symmetric steady state described above. This was done to enable the use of an analytical solution in place of a numerical solution of the model. Then, we considered the effects of an unanticipated monetary shock in the presence of a one-period nominal factor price rigidity, i.e. a one-period wage rigidity. Given that all factor prices are fully flexible after one period, the system reaches a new steady state equilibrium in just one period. As a result, monetary shock effects have only two-period dynamics: The short-run effects, which occurred just one period after the shock when wages were rigid, and the long-run effects, which occurred the second period after the shock when all prices were fully flexible. This prompts an introduction of the following notation.

Suppose that at the time *t=0*, the system was in the original symmetric steady state described by variables with a subscript *0*. Denote all variables at the time *t=2*, when the system reached new steady state with an overbar. Denote all intermediate short-run variables at the time *t=1* with a subscript *1*. Finally, the short-run and the long-run percentage deviations of variable x from initial steady state are correspondingly given by

Equation 21 Notation for Log-Linearization

$$\tilde{x} \equiv \frac{x_1 - x_0}{x_0} \approx d\ln x, \quad short-run\ deviation$$

$$\hat{x} \equiv \frac{\bar{x} - x_0}{x_0} \approx d\ln x, \quad long-run\ deviation$$

We proceed in the solution along the same line as presented in Lane (1999a). As we are interested here in the changes to each of the components of total consumption and price index, it is convenient to work with equations in disaggregated form, which can always be derived from definitions in Equation 2 and Equation 6, and the link given in Equation 32. Consider a permanent monetary expansion: $\tilde{M} = \hat{M} > 0$. First, one notices that with constant endowment in tradeables, the long-run change in consumption of tradeables is only possible through the current account movements in a form of earnings on accumulated net foreign assets, bonds, $\hat{C}_T = r\frac{dB}{\Omega_0}$. In turn, this build up of net foreign assets is only possible through the short-run current account surplus, $\frac{dB}{\Omega_0} = \tilde{Y}_T - \tilde{C}_T = -\tilde{C}_T$. Hence, there is a direct link between short-run and long-run consumption of tradeables

Equation 22 Tradeables Consumption Link

$$\hat{C}_T = -r\tilde{C}_T$$

Further, because wages are fixed in the short-run from Equation 13 we derive

Equation 23 Short-Run Product Prices

$$\tilde{P}_N = 0\,.$$

Log-linearization of the Euler equation for traded goods consumption Equation 15 yields

Equation 24

$$\hat{C}_T - \tilde{C}_T = \left(\frac{1}{\rho} - \theta\right)(\hat{P}_T - \tilde{P}_T - \hat{P}_N)\,,$$

where the log-linearized total consumption-based price index and Equation 23 were used.

From Equation 18, we can link long-run changes in tradeables and non-tradeables consumption goods

Equation 25

$$\hat{C}_N - \hat{C}_T = -\theta(\hat{P}_N - \hat{P}_T)$$

In the long-run, changes in consumption of nontradeables must equal the changes in output. From the last equation of Equation 14, where Ω is substituted from the second equation of Equation 32 and the total price index from Equation 6, we obtain

Equation 26 Long-Run Nontradeables Consumption

$$\hat{C}_N = \frac{1-\rho\theta}{\rho+\nu-1}\gamma(\hat{P}_N - \hat{P}_T)$$

However, in the short-run with sticky wages, the last equation of Equation 14 is not binding and the changes in output for nontradeables is demand determined. From Equation 18 we obtain

Equation 27 Short-Run Nontradeables Consumption

$$\tilde{Y}_N = \tilde{C}_N = \tilde{C}_T + \theta \cdot \tilde{P}_T$$

Combining Equation 26 and Equation 25, we can derive the long-run changes in consumption of tradeables as a function of a long-run relative price change:

Equation 28 Long-Run Tradeables Consumption

$$\hat{C}_T = (\theta + \gamma\frac{1-\rho\theta}{\rho+\nu-1})(\hat{P}_N - \hat{P}_T)$$

Finally, we log-linearized the money demand equation, which is given by the second and third equations of Equation 14, or alternatively by Equation 16. These are the only complicated expressions for log-linearization and some details are presented in Appendix *Log-Linearization*. Equilibrium conditions for money market in the short-run and the long-run are given by

Equation 29 Log-Linearized Money Demand

$$\frac{\rho}{\varepsilon}\tilde{C}_T - \left[\frac{1}{r\varepsilon} + \frac{1}{r\alpha(M_0/P_0)}\right]\hat{P}_T + \left[\frac{1}{r\varepsilon} + \frac{1}{r\alpha(M_0/P_0)} + \gamma + \frac{(1-\gamma)\rho\theta}{\varepsilon}\right]\tilde{P}_T = \hat{M},$$

$$\frac{\rho}{\varepsilon}\hat{C}_T + \left[\gamma + \frac{(1-\gamma)\rho\theta}{\varepsilon}\right]\hat{P}_T + (1-\gamma)\left(1-\frac{\rho\theta}{\varepsilon}\right)\hat{P}_N = \hat{M}$$

All eight unknown variables $\left\{\tilde{C}_T, \hat{C}_T, \tilde{C}_N, \hat{C}_N, \tilde{P}_T, \hat{P}_T, \tilde{P}_N, \hat{P}_N\right\}$, which describe short-run and long-run effects of an unanticipated monetary expansion, can be found from eight linear independent equations: from Equation 22 through to Equation 29, with the exception of Equation 25, which is the difference between Equation 28 and Equation 26.

Using Equation 22 and Equation 23, where necessary, the system dimension can be reduced by two to six equations in six variables $\left\{\hat{C}_T, \tilde{C}_N, \hat{C}_N, \tilde{P}_T, \hat{P}_T, \hat{P}_N\right\}$. The solution to this system of six linear independent equations can be found in general case and is presented in the Appendix *Linearized model solution*. However, the very complicated structure of expressions for coefficients, as functions of model parameters, is difficult to comprehend and sign primarily because such subexpressions as A and D are not definitely signed in the domain of admissible parameter values for ρ and θ.

Notwithstanding this complication, a thorough investigation of the linear system suggests that the following partition, based on the relation between the values of the intertemporal and intratemporal elasticities of substitution of consumption, exhausts all possible cases for coefficient signs. For the purpose of this paper, the crucial parameters from the economic viewpoint are γ, ε, ρ, and θ. Parameter γ is the share of tradeables in the total consumption index and can serve as a proxy for the openness of the economy; hence, it describes the level of a small open economy's dependence on the rest of the world. Parameter $1/\varepsilon$ represents the elasticity of intertemporal substitution of money services in the utility and will prove to be a crucial parameter in determining whether or not the nominal exchange rate (equal in our model to the price of tradeables) overshoots in response to an unanticipated monetary shock. Parameters $1/\rho$ and θ represent correspondingly intertemporal and intratemporal elasticities of substitution of consumption. These parameters determine the relative magnitude of the effect of the changes in the ratio (P_T/P) on the consumption of tradeables (C_T), and in turn, on the total consumption index (Ω), (see Equation 15 and comments below).

The previous parameter considerations suggest fixing the numeric values of less important technical parameters and exploring the behavior of the system coefficients as functions of γ and ε for three separate cases: Case 1, in which $(1/\rho)<\theta$; Case 2, in which $(1/\rho)>\theta$; and Case 3, in which $(1/\rho)=\theta$. The following numeric values were assigned to other parameters: $\alpha=2$, $k=0.5$, $\chi=1$, $\upsilon=2$, $\varphi=3$, $\phi=4$, and $r=0.1$. The values of γ naturally lie on the unit internal $[0,1]$. The range of values for ε was chosen to cover the interval from one to ten $[1,10]$, with $\varepsilon=1$ covering an extreme case of logarithmic utility in money services and $\varepsilon=10$ being larger than the largest typical value used in numeric simulation papers in a "new open economy macroeconomics" literature strand[8]. The behaviour of coefficients is best summarized by graphic means of the three-dimensional surface plots presented in Appendix *Graphic representation of the log-linearized model solution*. The Table 1 presents the model response to an unanticipated monetary shock (a unit step) in compact form.

Table 1 Model Response to an Unanticipated Monetary Shock[9]

Variable Name	**Notation**	**Case 1** $(1/\rho)<\theta$	**Case 2** $(1/\rho)>\theta$	**Case 3** $(1/\rho)=\theta$
Long-Run Tradeables Consumption	$\hat{C}_T$	+	-	0
Short-Run Nontradeables Consumption	$\tilde{C}_N$	+	+	+
Long-Run Nontradeables Consumption	$\hat{C}_N$	-	-	0
Short-Run Tradeables Prices	$\tilde{P}_T$	+,*	+,**	+,*
Long-Run Tradeables Prices	$\hat{P}_T$	+	+,**	1
Long-Run Nontradeables Prices	$\hat{P}_N$	+,*	+	1

[8] The highest value, $\varepsilon=9$, is met in Andersen and Beier (1999) and Senay (1999). Other typical values are: $\varepsilon=8$ in Betts and Devereux (1999); $\varepsilon=6$ in Chari et al (1998); and $\varepsilon=5$ and 1 in Bergin and Feenstra (1999).

[9] Table notation: plus sign indicates positive response; minus sign indicates negative response; single asterisk (*) indicates that overshooting is possible for some range of values of γ and ε; and double asterisk (**) indicates overshooting has taken place for the whole considered range of γ and ε values.

It is interesting to note that all signs are in agreement with the findings by Lane (1999a), despite differences in our models. The model presented by Lane (1999a) does not have foreign currency, and instead of labour effort, the utility function includes nontradeables output.

A discussion of the solution begins with the response of a current account to an unanticipated monetary shock. From Equation 22 and the paragraph preceding it, one can see that the short-run current account surplus is equal to the negative in the short-run tradeables consumption, which in turn is negatively related to the long-run tradeables consumption. Therefore, the short-run current account movement is provided in the first line in our Table 1, where it progresses into surplus in Case 1 (which corresponds to the traditional Mundell-Fleming set up), into deficit in Case 2, and maintains a balance in Case 3. Thus, the theoretical model does not specify the direction of the response of a current account to an unanticipated monetary shock.

From the discussion above, a question emerges for empirical research: Can empirical observations deliver a more definite resolution? For illustrative purposes, 13 transition economies in Central and Eastern Europe and the Baltic states are presented in Table 2 (see Appendix *Data for transition economies*). Each of these countries experienced an unanticipated monetary shock, which is identified with the year when inflation peaked – often coinciding with the same year that reform and stabilization programs started. Of these countries, only six had a flexible exchange rate regime at the time: Albania, Bulgaria, Latvia, Lithuania, Romania, and Slovenia. Among these six countries, four responded with the short-run current account surplus falling into the traditional category of Case 1, while Bulgaria and Lithuania responded with the short-run current account deficit as Case 2 predicts. Does this mean that intertemporal elasticity of substitution is greater than intratemporal elasticity for Bulgaria and Lithuania, and vice versa for the other four countries?

These findings, of course, should be treated with great caution for several reasons. First, from a technical standpoint, the availability of data quality on transition economies, most especially in the early years and in the area of balance of payment statistics, is very poor. Second, from a theoretical perspective, one could argue that transition economies were not in equilibrium when they experienced monetary shock. Indeed, a pre-reform initial condition assessment conducted by EBRD confirms this (see EBRD Transition Report 1999, Box 2.1, p. 28). Specifically, amounts of foreign real money balances in the form of US dollar- and German mark-denominated private savings were not negligible. Finally, one may argue that the size of monetary shock these countries experienced was not small enough for accurate linear approximation.

Turning to the consumption and production of nontraded goods in the long-run, we confirm an interesting finding by Lane (1999a, pp. 10-11), that is, in a new steady-state, the consumption and production of nontraded goods is lower in both Cases 1 and 2. This occurs because of a change through the current account movements of a new steady-state level of traded goods consumption which exerts a wealth effect on the desired consumption level of nontraded goods and influences a household's decision on optimal labour supply to nontraded goods production. Results show that in both cases, the size of the negative effect is greater.

The real exchange rate is defined as the relative price of nontradeables in terms of tradeables. The long-run response of the real exchange rate to an unanticipated monetary shock is given by the difference ($\hat{P}_N - \hat{P}_T$). It is positive for Case 1 (see Figure 20 in Appendix *Graphic representation of the log-linearized model solution*) in that the real exchange rate appreciates, is negative for Case 2, and is unchanged for Case 3.

Finally, turning to the dollarization phenomenon, we can make the following conclusion. Assume that the behaviour of the level of foreign real money balances is a good proxy for the behaviour of the level of dollarization. Then the third equation of Equation 14 indicates that the level of foreign real money balances depends positively on the rate of depreciation of exchange rate $\Delta E \equiv P_{T,t+1}/P_{T,t}$, which is positive for all three cases (see Figure 17, Figure 18, and Figure 19). Therefore, in the short-run, the level of dollarization is positive, rising from zero in response to an unanticipated monetary shock in all cases. In the long run, when the system reaches a new equilibrium and $\Delta E=0$, the level of dollarization as well as foreign real money balances returns to zero. Hence, in this particular model setup dollarization is a transitory, disequilibrium phenomenon. It does not exhibit any hysteresis or ratchet effect. This description closely suits the experience of some transition economies, which had fast and successful stabilization, for example, Poland[10].

[10] See figures 1 and 2 for inflation rate and the level of dollarization in different transition economies in Sahay and Vegh (1995, pp. 10-13). They also mention such countries as Estonia, Lithuania, and Mongolia as cases of stabilization with de-dollarization.

Completing the discussion, we consider the influence of γ and ε parameters on the response of the system to an unanticipated monetary shock. First, we address the issue of economic openness and its effects on economic performance. Considering parameter γ (share of traded goods in total consumption) as a good proxy for the level of openness of the economy, the solution shows that higher openness leads to less overshooting of the nominal exchange rate (Figure 10, Figure 14) or eliminate overshooting entirely (Figure 4 and Figure 15). Further, the effects of monetary shock on the long-run real exchange rate become smaller as γ increases (Figure 20). Also, one can see that greater openness dampens the short-run response of current account to monetary shocks (Figure 1 and Figure 7). Therefore, one can argue that greater economic openness should be promoted as it plays a stabilizing role for the economy in the face of monetary shocks[11].

Turning to the effects of ε we can observe that the effects of an unanticipated monetary shock are stronger when ε is higher; that is, the lower the elasticity of intertemporal substitution of money services ($1/\varepsilon$). Many of the figures in Appendix *Graphic representation of the log-linearized model solution* indicate this kind of dependence, except Figure 2, Figure 3, Figure 7, Figure 9, and Figure 12.

Conclusions

The issue of the effects of an unanticipated monetary shock in a small open economy with dollarization, factor price rigidities, and nontradeables was reexamined in a general equilibrium, intertemporal optimizing model. The framework of an earlier research was extended to incorporate the foreign real money balances into a representative agent utility function, and therefore, to account for the phenomenon of dollarization characteristic of transition economies. The solution was derived for a log-linearized version of the model and presented in Table 1 and in other figures.

[11] This conclusion is in line with the finding by Lane (1997) that trade openness is an important determinant of average inflation over the long-run in open economies, with more open economies having lower inflation rates. The behaviour of the inflation rate is a good proxy for the general level of instability in the economy.

The major finding of this research is that in the event of small monetary shocks, the presence of dollarization does not alter an important solution partition scheme as discussed in Obstfeld and Rogoff (1996, pp. 234-235) and Lane (1999a). The scheme relates the sign of response of consumption, current account balance, and other macroeconomic variables to the difference between *inter*temporal and *intra*temporal elasticities of substitutions of the total consumption index, $1/\rho - \theta$. Further, the signs of responses themselves are in agreement with earlier research findings by Lane (1999a).

Overshooting regions for prices and exchange rate responses to an unanticipated monetary shock were found to depend on the elasticity of intertemporal substitution of money services ($1/\varepsilon$) and the share of traded goods in total consumption (γ), which is also a proxy for openness of the economy. The results also show that one can argue for greater economic openness since it plays a stabilizing role in the economy in the event of monetary shocks. Finally, we derived that the level of foreign real money balances and, hence, the level of dollarization will increase in the short-run response to an unanticipated monetary shock.

As to a future research agenda, two major amendments should be sought immediately. The first is related to the set-up of nominal rigidities. It would be beneficial to extend the present framework in which wages are pre-set one period ahead to a more realistic framework in which wage contracts are staggered over multiple periods. This will yield the true (as opposed to the present two-period) dynamic adjustment to the effects of monetary shock. The second amendment is related to a solution procedure. As even for the log-linearized model the solution is too complicated, one may seek a full numeric treatment of the original nonlinear system. This would render unnecessary the size constraint on the magnitude of an unanticipated monetary shock, allowing one to consider the effects of large monetary shocks instead.

Appendices

The total consumption-based price index

Following Obstfeld and Rogoff (1996, pp. 222-3, 227-8), we derive the total consumption-based price index in two steps. First, we derive consumption demands for tradeables and nontradeables given total expenditures. Formally, we solve the following problem:

Equation 30 Derivation of Consumption Demands

$$\underset{\{C_T, C_N\}}{Max}\ \Omega = \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \quad subject\ to \quad Z = P_T C_T + P_N C_N$$

This maximization problem yields the following consumption demands:

Equation 31 Demand Functions for Tradeables and Nontradeables

$$P_T C_T = \frac{\gamma Z}{\gamma + (1-\gamma)\left(\frac{P_N}{P_T}\right)^{1-\theta}}, \quad P_N C_N = \frac{(1-\gamma)\left(\frac{P_N}{P_T}\right)^{1-\theta} Z}{\gamma + (1-\gamma)\left(\frac{P_N}{P_T}\right)^{1-\theta}}$$

In the second step, we substitute these demand functions into *Ω*, and use the fact that *P* is defined as the minimum expenditures, such that *Ω=1*,

$$\left\{\gamma^{\frac{1}{\theta}}\left[\frac{\gamma P}{\left(P_T\gamma + P_T(1-\gamma)\left(\frac{P_N}{P_T}\right)^{1-\theta}\right)}\right]^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}}\left[\frac{(1-\gamma)\left(\frac{P_N}{P_T}\right)^{1-\theta} P}{\left(P_N\gamma + P_N(1-\gamma)\left(\frac{P_N}{P_T}\right)^{1-\theta}\right)}\right]^{\frac{\theta-1}{\theta}}\right\} = 1$$

from which the formula in Equation 6 follows.

Notice that for an optimizing agent *Z=PΩ*. This allows us, using Equation 6, to rewrite the demand functions in Equation 31 as

Equation 32 Demands as Proportions of the Real Consumption Index

$$C_T = \gamma \left(\frac{P_T}{P} \right)^{-\theta} \Omega, \quad C_N = (1-\gamma) \left(\frac{P_N}{P} \right)^{-\theta} \Omega$$

The formulas in Equation 32 show that the demand for a good is proportional to the real consumption index, with a proportionality coefficient being an isoelastic function of the ratio of the good's price to the total price index. Further, they solve an *intra*temporal consumption problem for an optimizing agent with respect to tradeables and nontradeables consumption.

The consumption-based price index for nontraded goods

Following Obstfeld and Rogoff (1996, p. 227), we define the consumption-based price index for nontraded goods, P_N, as the minimum expenditure $Z_N = P_N C_N$ which buys one unit of real consumption of nontraded goods, C_N. Formally, P_N solves the following problem.

Equation 33 Derivation of the Price Index for Nontraded Goods

$$\underset{c(z)}{Min}\, Z_N = P_N C_N = \int_0^1 p_N(z) c_N(z) dz, \textit{ subject to} \quad C_N = \left[\int_0^1 c_N(z)^{\frac{\phi-1}{\phi}} dz \right]^{\frac{\phi}{\phi-1}} = 1$$

The first-order conditions can be found by differentiating [with respect to $c_N(z)$] the Lagrangian expression

$$L = \int_0^1 p_N(z) c_N(z) dz - \lambda \cdot \left[\int_0^1 c_N(z)^{\frac{\phi-1}{\phi}} dz - 1 \right]$$

It follows that

Equation 34 First-Order Condition for P_N

$$c_N(z) = p_N(z)^{-\phi} \cdot \left[\frac{\phi}{\lambda(\phi-1)} \right]^{-\phi}$$

Substituting this into the constraint yields

Equation 35

$$\left[\int_0^1 p_N(z)^{1-\phi}\,dz\right]^{\frac{1}{1-\phi}} = \frac{\lambda(\phi-1)}{\phi}$$

Now, from Equation 34, every nontraded good in expenditures receives the following weight

Equation 36

$$p_N(z)c_N(z) = p_N(z)^{1-\phi}\cdot\left[\frac{\lambda(\phi-1)}{\phi}\right]^{\phi}$$

Using Equation 35 and the definition of the consumption-based price index for nontraded goods, we obtain

$$P_N = \int_0^1 p_N(z)c_N(z)dz = \int_0^1 p_N(z)^{1-\phi}\left[\int_0^1 p_N(z)^{1-\phi}\,dz\right]^{\frac{\phi}{1-\phi}} dz =$$

$$\left[\int_0^1 p_N(z)^{1-\phi}\,dz\right]^{\frac{\phi}{1-\phi}}\cdot\left[\int_0^1 p_N(z)^{1-\phi}\,dz\right] = \left[\int_0^1 p_N(z)^{1-\phi}\,dz\right]^{\frac{1}{1-\phi}}$$

which is the exact same formula that appears in Equation 8.

Labour demand function

To derive labour demand function, we need to solve the problem of cost minimization by firm z given Equation 10 Production Function for Non-tradeables and Equation 11 Wage Index. Formally, the problem is

Equation 37 Cost Minimization

$$\underset{L^j(z)}{Min}\int_0^1 L^j(z)w^j dj, \quad subject\ to \quad Y_{Nt}(z)=\left[\int_0^1 L_t^j(z)^{\frac{\varphi-1}{\varphi}}dj\right]^{\frac{\varphi}{\varphi-1}}$$

From the first-order condition we have

$$L^j(z)=\left(\frac{w^j}{\lambda}\right)^{-\varphi}Y_{Nt}(z),$$

where λ is the Lagrange multiplier. Substituting this expression into the constraint, one can show that $\lambda=W$, and from the above expression, the labour demand schedule Equation 12 follows immediately.

Optimal product prices

Since production technologies and household preferences are identical across firms and households, we can restrict our attention to the case of symmetric equilibrium, where all firms behave identically and all households behave identically. In this case from Equation 11 and Equation 12 follows that $w^j=W$, and $L(z)=Y_N(z)$. The profit of the firm z is given by

Equation 38 Firm Profit

$$\Pi(z)=p_N(z)Y_N(z)-\int_0^1 L^j(z)w^j dj=\left[p_N(z)-W\right]\cdot Y_N(z)=\left[p_N(z)-W\right]\cdot\left(\frac{p_N(z)}{P_N}\right)^{-\phi}C_N,$$

where the last equality comes from the fact that monopolistic firm takes product demand given by Equation 9 into account. Now, the formal problem is

Equation 39 Firm Profit Maximization Problem

$$\underset{p_N(z)}{Max}\,\Pi(z) = \left[p_N(z) - W\right]\cdot\left(\frac{p_N(z)}{P_N}\right)^{-\phi} C_N$$

The first-order condition yields the optimal product price for the nontraded good z

$$p_N(z) = \frac{\phi}{\phi - 1}W$$

However, in a symmetric equilibrium this price will be the same for all goods, therefore, $p_N(z)=P_N$ for all z, and Equation 13 follows from the above expression.

Household's first-order conditions

To derive the first-order conditions for households, we first express the total consumption index Ω from the budget constraint Equation 5. This yields

$$\Omega_t = \frac{P_{Tt}}{P_t}(1+r)B_t - \frac{P_{Tt}}{P_t}B_{t+1} - \frac{M_t - M_{t-1}}{P_t} - \frac{P_{Tt}\left(M_t^* - M_{t-1}^*\right)}{P_t} - \frac{P_{Tt}}{P_t}\tau + \frac{P_{Tt}}{P_t}\bar{y}_T + \frac{w_t L_t}{P_t},$$

where the last term represents the households' real factor income. While performing utility maximization, the household takes into account the labour demand schedule given by Equation 12. By substituting Equation 12 into the above expression for the total consumption index Ω, and substituting it into the utility function given by Equation 1, we can perform an unconstrained utility maximization with respect to the household's choice variables: B_{t+1}, M_t, M_t^*, and w_t. Formally, the problem is

Equation 40 Household's Maximization Problem

$$\underset{\{B_{t+1}, M_t, M_t^*, w_t\}}{Maximize}\sum_{t=0}^{\infty}\beta^t\left[\frac{(\Omega_t)^{1-\rho}}{1-\rho} + \frac{\chi}{1-\varepsilon}(MS_t)^{1-\varepsilon} - \frac{k}{v}(L_t)^v\right],$$

where Ω is substituted from the above expression and L_t is substituted everywhere from Equation 12. Performing derivations yields

Equation 41

$$\frac{P_{Tt}}{P_t}\Omega_t^{-\rho} = \beta(1+r)\frac{P_{Tt+1}}{P_{t+1}}\Omega_{t+1}^{-\rho}$$

$$-\frac{1}{P_t}\Omega_t^{-\rho} + \frac{\beta}{P_{t+1}}\Omega_{t+1}^{-\rho} + \frac{\chi}{P_t}\left(MS_t\right)^{-\varepsilon} = 0$$

$$-\frac{P_{Tt}}{P_t}\Omega_t^{-\rho} + \frac{\beta P_{Tt+1}}{P_{t+1}}\Omega_{t+1}^{-\rho} + \frac{\chi P_{Tt}}{P_t}\left(MS_t\right)^{-\varepsilon}\frac{dg(m_t^*)}{dm_t^*} = 0 ,$$

$$\frac{1}{P_t}\Omega_t^{-\rho}(1-\varphi) + \frac{k\varphi}{w_t}L_t^{\nu-1} = 0$$

where we denote foreign real money balances with m_t^*. Further we assume $\beta(1+r)=1$. By multiplying the second equation by P_t and substituting Ω_{t+1} from the 1st equation, and rearranging, the second equation from Equation 14 is produced. Similar operations over the third equation of Equation 41 yield

$$\chi\left(MS_t\right)^{-\varepsilon}\frac{dg(m_t^*)}{dm_t^*} = (1-\beta)\Omega_t^{-\rho}$$

Dividing this equation by the second equation of Equation 14 yields the third of equations from Equation 14, demand for foreign real money balances. The last of equations from Equation 14, labour-leisure trade-off condition, is a rearrangement of the last equation in Equation 41.

Iterating the period budget constraint given by Equation 5 forward, one can show that an appropriate transversality condition is given by

Equation 42 Transversality Condition

$$\lim_{T\to\infty}\left(\frac{1}{1+r}\right)^T\left(B_{t+1+T} + \frac{M_{t+T}}{P_{t+T}} + \frac{P_{T,t+T}M_{t+T}^*}{P_{t+T}}\right) = 0$$

This transversality condition on a household's total financial assets has the usual meaning. At an infinite time horizon, a household's total financial assets can be neither negative (i.e. because lenders do not allow one to borrow over an infinite period without repaying the debt [e.g., *no-Ponzi-game* condition]), nor positive (i.e. given the positive marginal utility of consumption, it will not be optimal since it is possible to raise one's lifetime utility by consuming a bit more).

Log-Linearization

The log-linearization procedure consists of two successive operations. First, we apply the logarithm function to the expression of interest. Second, we construct the Taylor series expansion of the resulting expression around equilibrium steady-state values and keep only linear terms, assuming that terms of higher orders are negligible.

In performing these operations, the only tricky case is when one must log-linearize the sum of two functions. For this case, the following general formula applies. Let $F=ln\{f(x,y)+g(z,w)\}$, where *ln* stands for natural logarithm function, $f(x,y)$ and $g(z,w)$ are any two functions and (z,w) can coincide with (x,y). Then we have

Equation 43 General Log-Linearization Formula

$$dF=\left(\frac{f_x\cdot x}{f+g}\right)_0 d\ln(x)+\left(\frac{f_y\cdot y}{f+g}\right)_0 d\ln(y)+\left(\frac{g_z\cdot z}{f+g}\right)_0 d\ln(z)+\left(\frac{g_w\cdot w}{f+g}\right)_0 d\ln(w),$$

where round brackets containing f and g functions and corresponding partial derivatives are evaluated at the steady-state equilibrium values.

Applying the described procedure of log-linearization and the above formula to Equation 6 Total Consumption-Based Price Index yields

Equation 44 Log-Linearized Price Index

$$\hat{P}=\gamma\hat{P}_T+(1-\gamma)\hat{P}_N,$$

where we wrote the expression for the long-run deviations of the total price index. The expression for the short-run deviations has exactly the same structure, except for short-run changes in the price of nontradeables being zero by Equation 23.

Given the definition of the utility of foreign real money balances in Equation 4 we substitute the third equation of Equation 14 into the second and obtain the following money demand equation for log-linearization

Equation 45

$$\chi\left\{\frac{M_t}{P_t}+\frac{\beta}{\alpha}\cdot\frac{P_{Tt+1}-P_{Tt}}{P_{Tt+1}-\beta P_{Tt}}\right\}^{-\varepsilon}=\left(1-\frac{\beta P_{Tt}}{P_{Tt+1}}\right)\Omega_t^{-\rho}.$$

Applying the log-linearization procedure to the right-hand-side, yields for short-run and long-run deviations correspondingly

Equation 46

$$\frac{1}{r}\cdot\left(\hat{P}_T-\tilde{P}_T\right)-\rho\cdot\left[\tilde{C}_T+\theta(1-\gamma)\tilde{P}_T\right],\quad -\rho\cdot\left[\hat{C}_T+\theta(1-\gamma)(\hat{P}_T-\hat{P}_N)\right],$$

where Ω was substituted by C_T from Equation 32, and $r=(1-\beta)/\beta$. The left-hand-side yields for short-run and long-run deviations correspondingly

Equation 47

$$-\varepsilon\cdot\left\{\hat{M}-\tilde{P}+\frac{1}{\left(M_0/P_0\right)\alpha r}\cdot(\hat{P}_T-\tilde{P}_T)\right\},\quad -\varepsilon\cdot\left\{\hat{M}-\hat{P}\right\},$$

where initial money balances are determined by model parameters from Equation 20. Combining Equation 46 and Equation 47, using Equation 44 and collecting terms, yields Equation 29.

Finally, log-linearization of the first-order condition for the real foreign money balances (the third equation of Equation 14) yields

Equation 48 Log-Linearized Real Foreign Money Balances

$$\tilde{M}^*-\tilde{P}+\tilde{P}_T=\frac{1}{r\cdot\ln\left(1-\frac{1}{1+r}\right)},\quad \hat{M}^*-\hat{P}+\hat{P}_T=0.$$

The result shows that in the long-run, real foreign money balances are zero again.

Linearized model solution

First, we can write our six linear equations in a matrix form.

Equation 49 Log-Linearized Model in a Matrix Form

$$\begin{pmatrix} \frac{1}{r} & -1 & 0 & \theta & 0 & 0 \\ 1+\frac{1}{r} & 0 & 0 & D & -D & D \\ 0 & 0 & 1 & 0 & \gamma A & -\gamma A \\ 1 & 0 & 0 & 0 & \theta+\gamma A & -(\theta+\gamma A) \\ \frac{-\rho}{r\varepsilon} & 0 & 0 & C+B & -C & 0 \\ \frac{\rho}{\varepsilon} & 0 & 0 & 0 & B & 1-B \end{pmatrix} \cdot \begin{pmatrix} \hat{C}_T \\ \tilde{C}_N \\ \hat{C}_N \\ \tilde{P}_T \\ \hat{P}_T \\ \hat{P}_N \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \hat{M} \\ \hat{M} \end{pmatrix},$$

where for convenience the following subexpression are introduced

Equation 50 Notation for Matrix Form

$$A = \frac{1-\rho\theta}{\rho+\nu-1}, \quad B = \gamma + \frac{(1-\gamma)\rho\theta}{\varepsilon}, \quad C = \frac{1}{r\varepsilon} + \frac{1}{r\alpha\left(M_0/P_0\right)}, \quad D = (1-\gamma)\left(\frac{1}{\rho} - \theta\right)$$

It is clear that B and C are always positive for an admissible range of parameters values, while A and D can change sign depending on values of ρ and θ. Further, A and D are equal to zero when $(1/\rho)=\theta$. The general solution to the system is given by

Equation 51 General Solution to Matrix Equation

$$\begin{pmatrix} \hat{C}_T \\ \tilde{C}_N \\ \hat{C}_N \\ \tilde{P}_T \\ \hat{P}_T \\ \hat{P}_N \end{pmatrix} = \begin{pmatrix} -(1+C)Dr\varepsilon(\gamma A+\theta) \\ (1+C)\varepsilon\left[(1+r)(D+\theta)\theta + \gamma A(D+(1+r)\theta)\right] \\ -(1+C)Dr\varepsilon\gamma A \\ (1+C)\varepsilon\left[Dr+(1+r)(\gamma A+\theta)\right] \\ (1+r)(\gamma A+\theta)(B+C)\varepsilon + D\left[(\gamma A+\theta)\rho + r((1+C)\varepsilon + (\gamma A+\theta)\rho)\right] \\ (1+r)(\gamma A+\theta)\left[(B+C)\varepsilon + D\rho\right] \end{pmatrix} \cdot \frac{\hat{M}}{\Delta},$$

where the common denominator Δ is given by

Δ=Bε[(1+C) Dr+(1+r) (γA+θ)]+ (γA+θ)[Dρ+C ((1+r)ε- Drρ)].

Finally, the solution is much simpler for the special case when *(1/ρ)=θ.*

Equation 52 Solution to Matrix Equation for the Special Case of *(1/•)=•*

$$\begin{pmatrix} \hat{C}_T \\ \tilde{C}_N \\ \hat{C}_N \\ \tilde{P}_T \\ \hat{P}_T \\ \hat{P}_N \end{pmatrix} = \begin{pmatrix} 0 \\ \dfrac{(1+C)\theta}{B+C} \\ 0 \\ \dfrac{1+C}{B+C} \\ 1 \\ 1 \end{pmatrix} \cdot \hat{M}$$

In particular, one can derive from Equation 50 that for ε >1 the nominal exchange rate always overshoot in the short-run ($\tilde{P}_T$) in response to a monetary shock.

Graphic representation of the log-linearized model solution

Solution given by Equation 51 can be considered as a function of *γ* and *ε* parameters for the three separate cases: Case 1, in which *(1/ρ)<θ*; Case 2, in which *(1/ρ)>θ*; and Case 3, in which *(1/ρ)=θ*. In particular, we assume the following numeric values for *ρ* and *θ*. For Case 1, we assume *ρ=4, θ=5*. For Case 2, we assume *ρ=0.25, θ=2*. For Case 3, we assume *θ=5*. The following numeric values were assigned to other parameters: *α=2, k=0.5, χ=1, υ=2, φ=3, ϕ=4, r=0.1*. The values of *γ* naturally lie on the unit internal *[0,1]*. The range of values for *ε* was chosen to cover the interval from one to ten *[1,10]*. With no loss of generality the money shock is assumed to be a unit step.

Below are graphical representations that depict the behavior of the solutions of the log-linearized model consecutively for Case 1, Case 2, and Case 3. The figures also show overshooting regions and short-run changes in real foreign money balances.

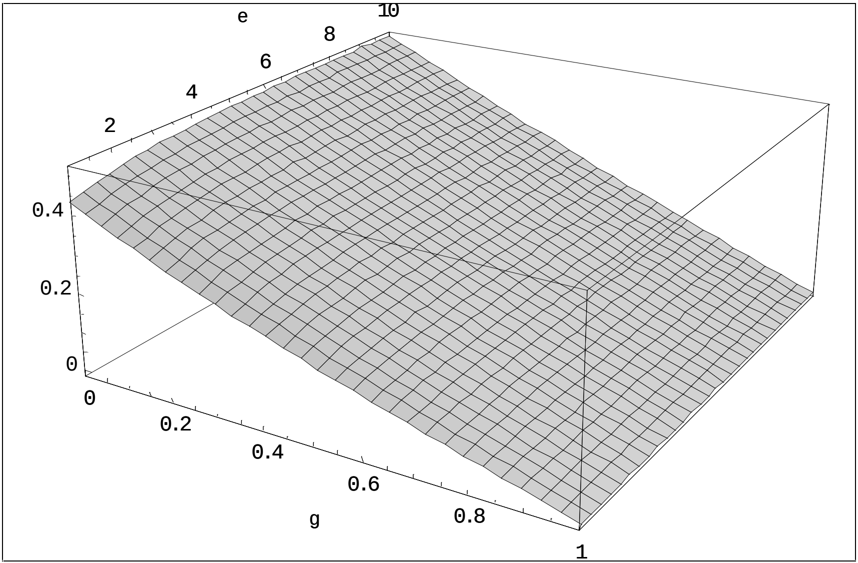

Figure 1 Long-run changes in tradeables consumption (Case 1)

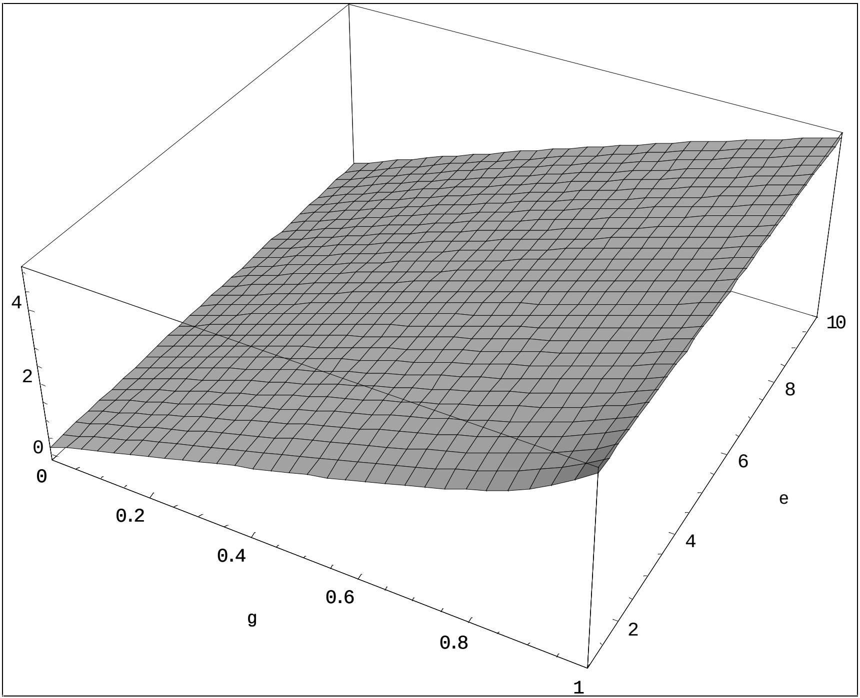

Figure 2 Short-run changes in nontradeables consumption (Case 1)

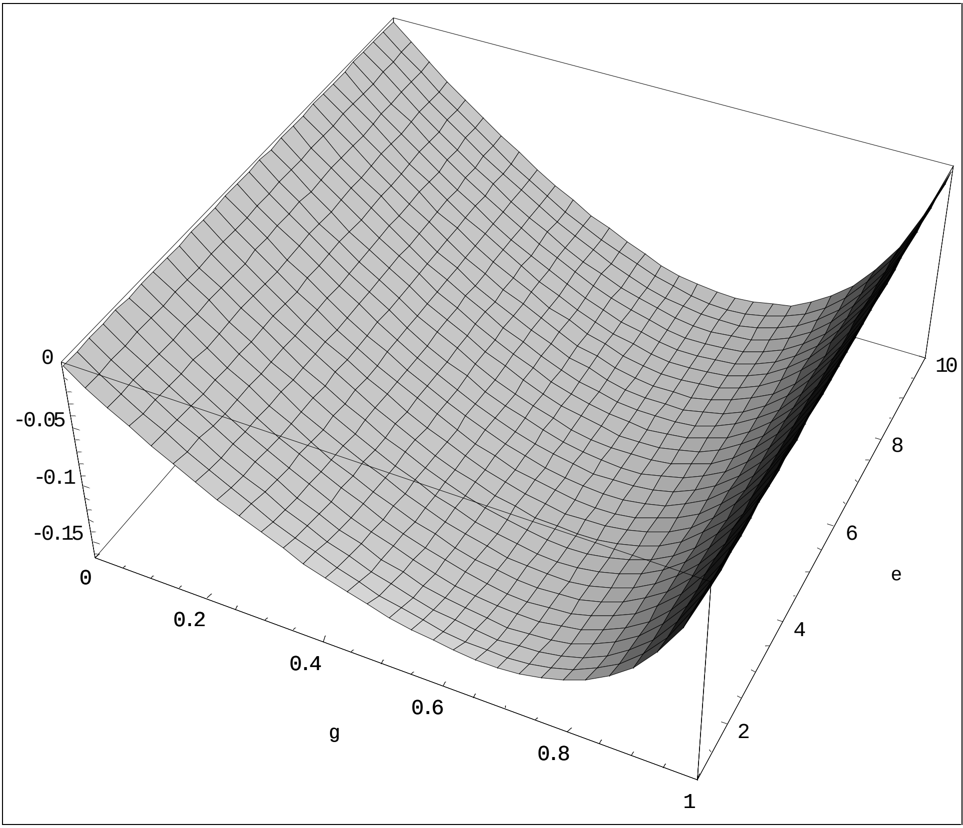

Figure 3 Long-run changes in nontradeables consumption (Case 1)

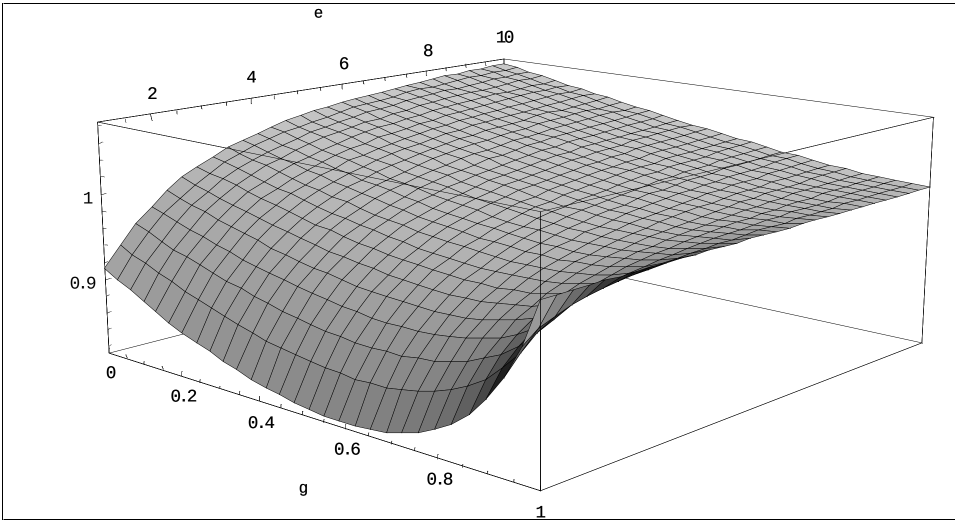

Figure 4 Short-run changes in tradeables price index (Case 1)

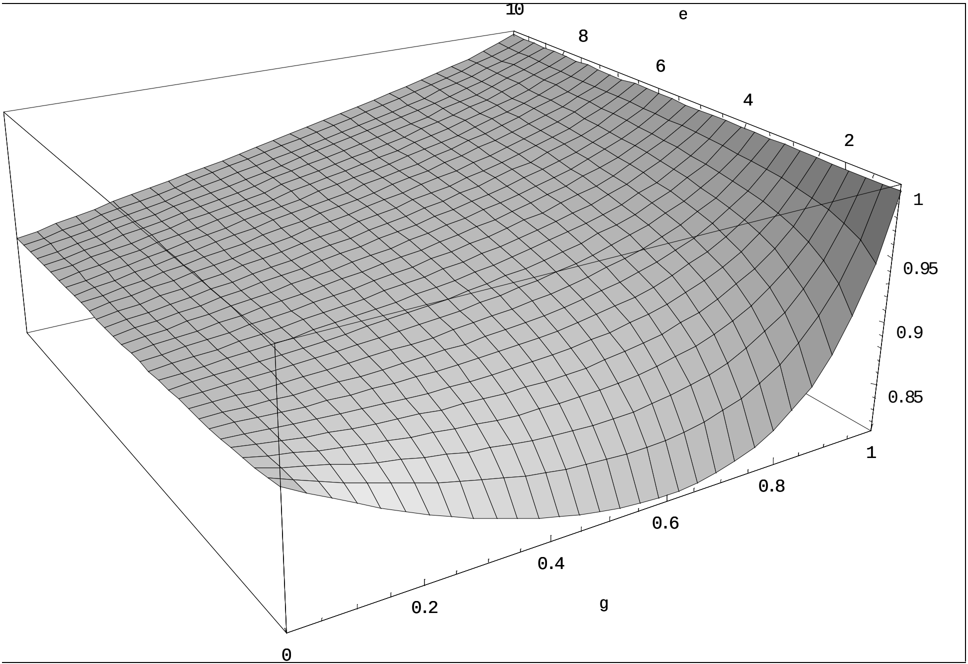

Figure 5 Long-run changes in tradeables price index (Case 1)

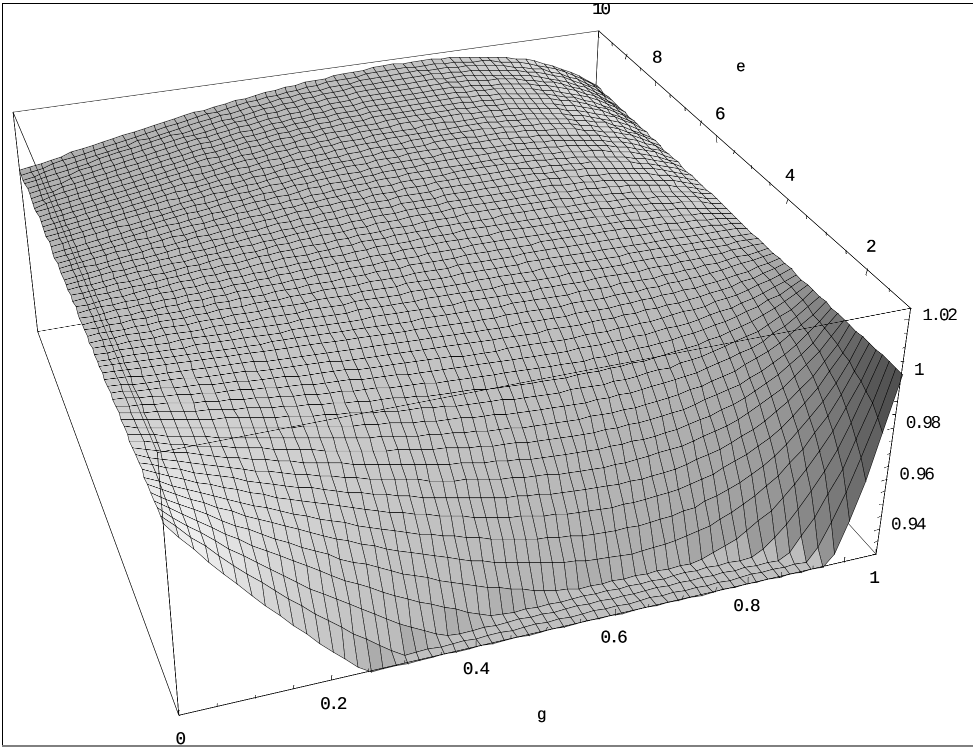

Figure 6 Long-run changes in nontradeables price index (Case 1)

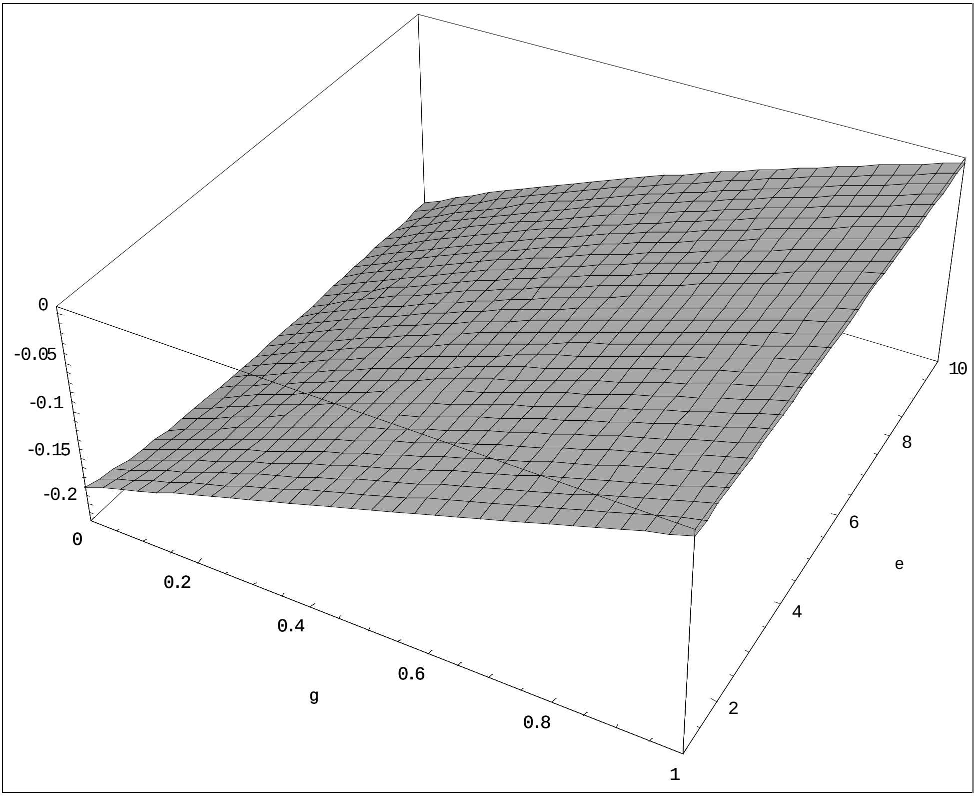

Figure 7 Long-run changes in tradeables consumption (Case 2)

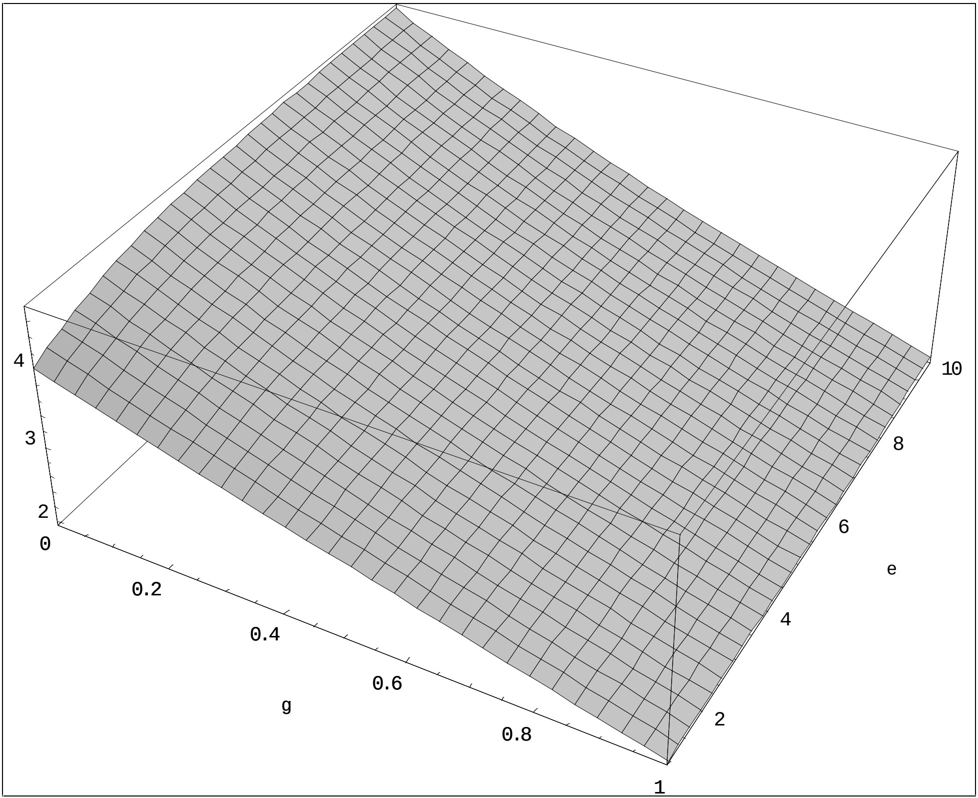

Figure 8 Short-run changes in nontradeables consumption (Case 2)

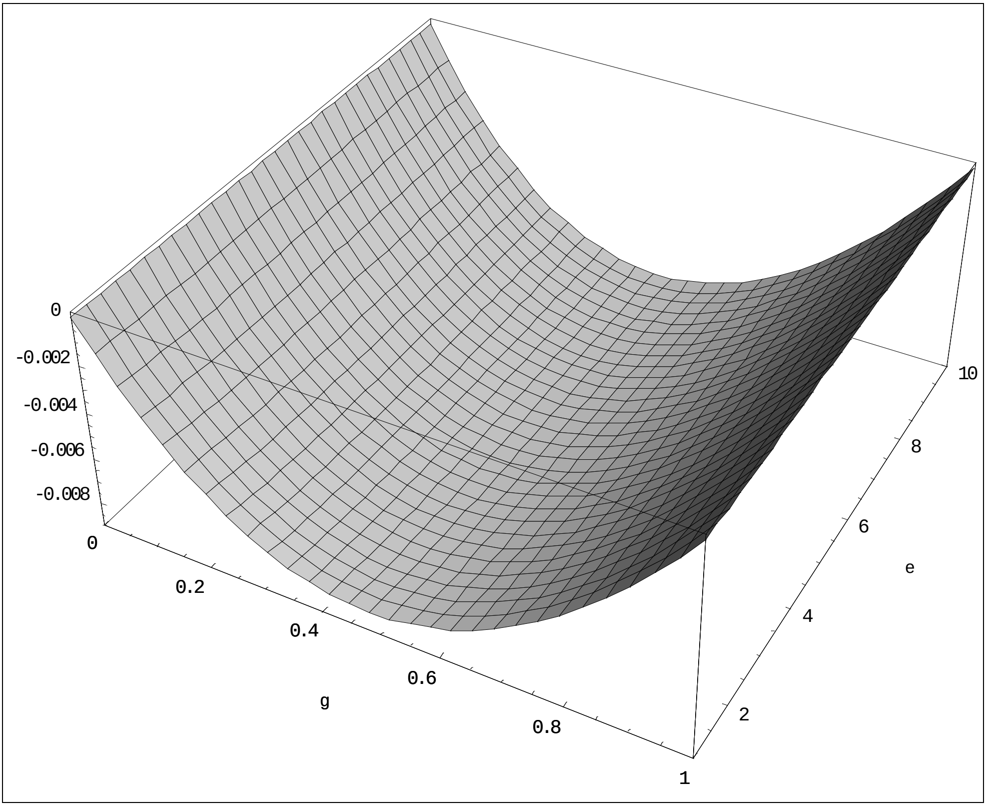

Figure 9 Long-run changes in nontradeables consumption (Case 2)

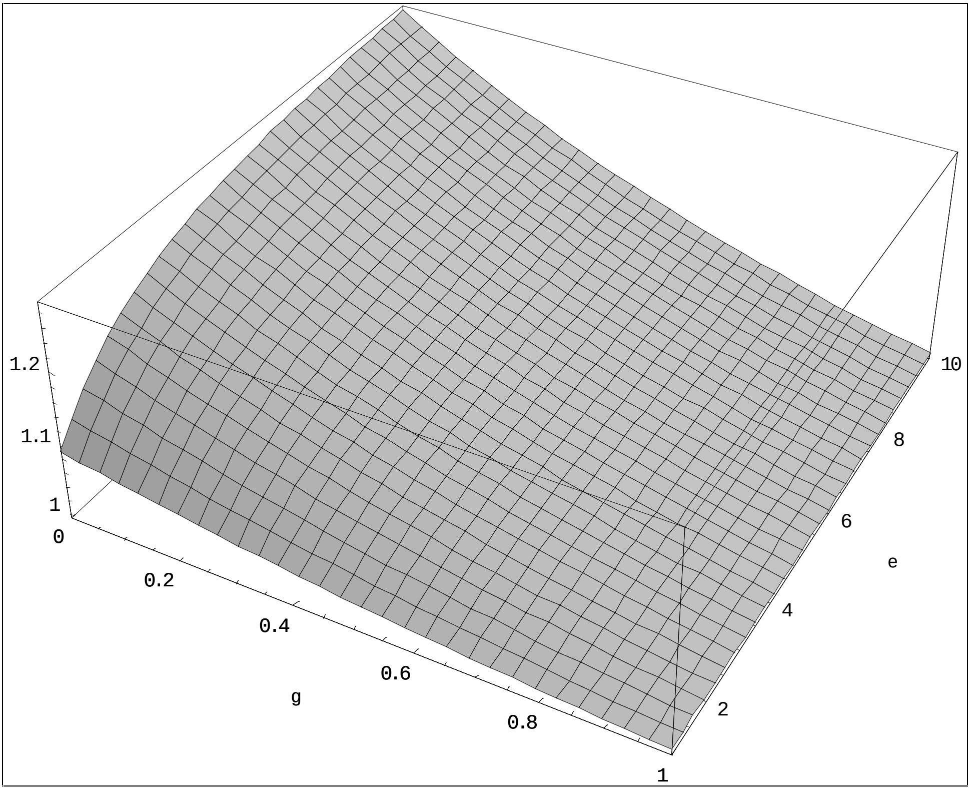

Figure 10 Short-run changes in tradeables price index (Case 2)

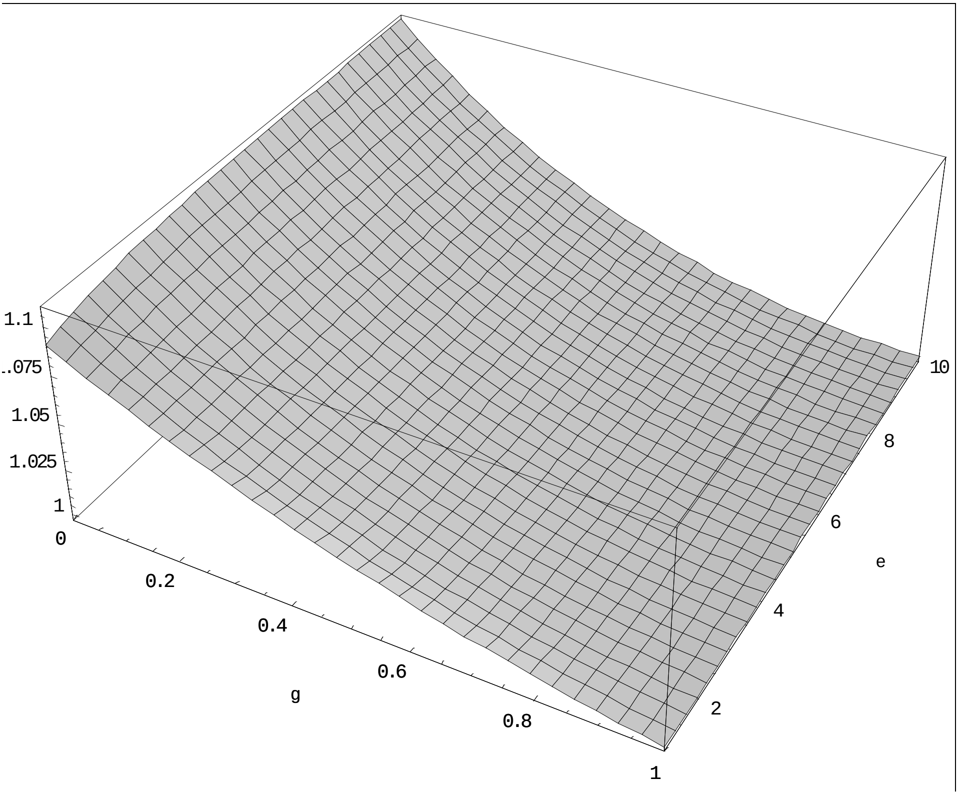

Figure 11 Long-run changes in tradeables price index (Case 2)

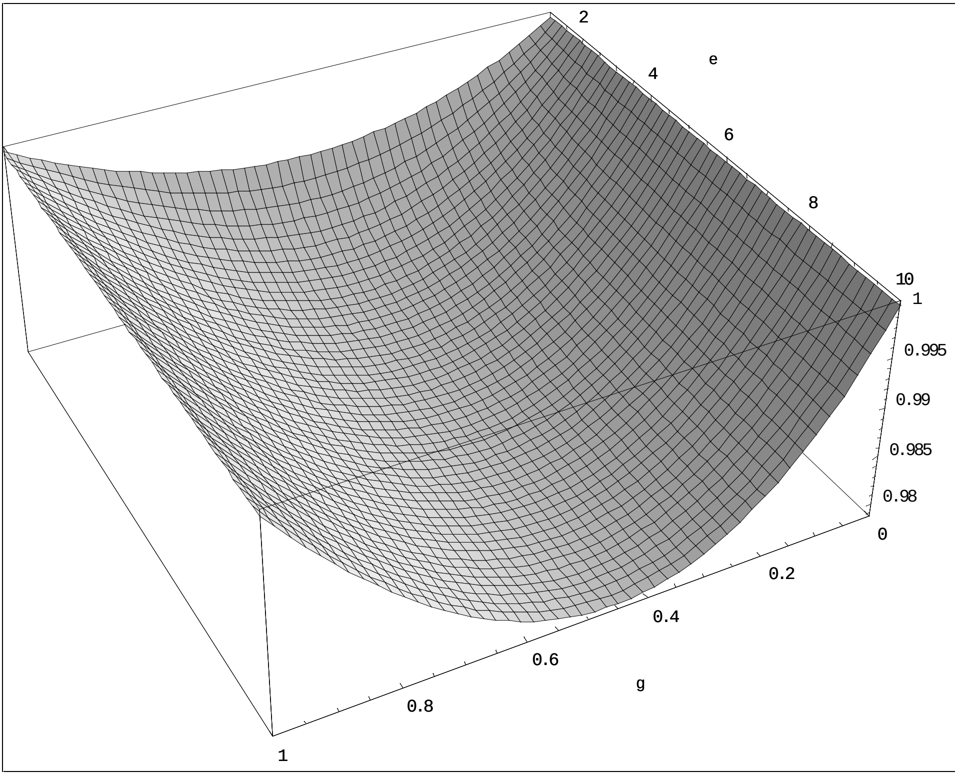

Figure 12 Long-run changes in nontradeables price index (Case 2)

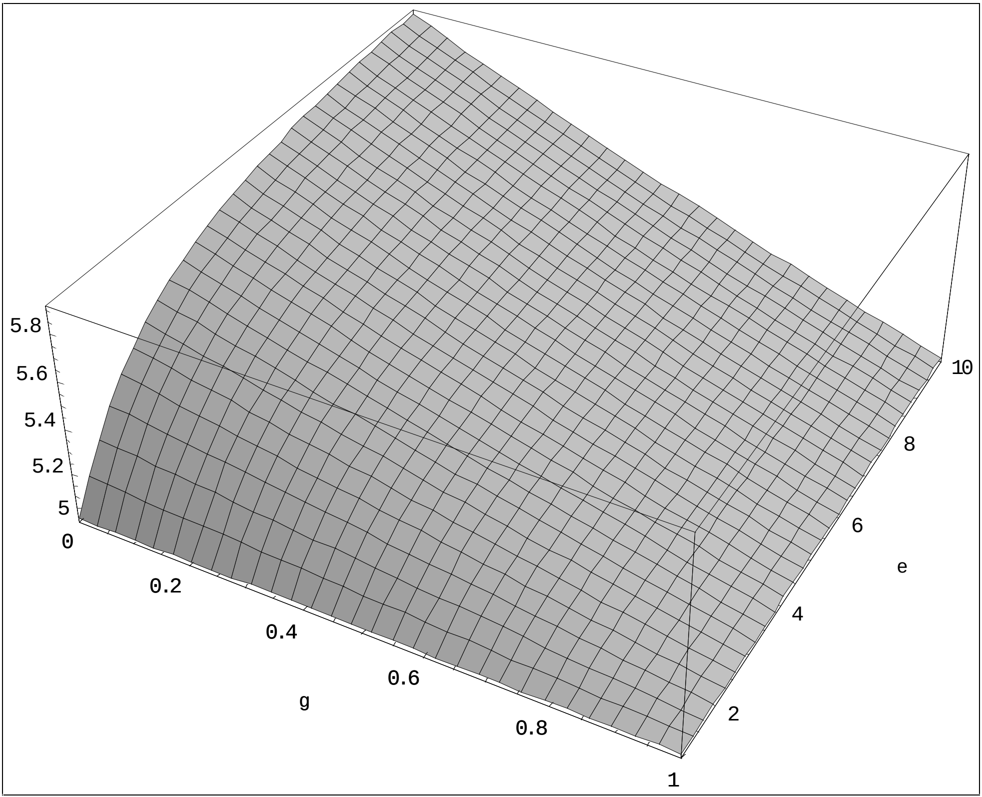

Figure 13 Short-run changes in nontradeables consumption (Case 3)

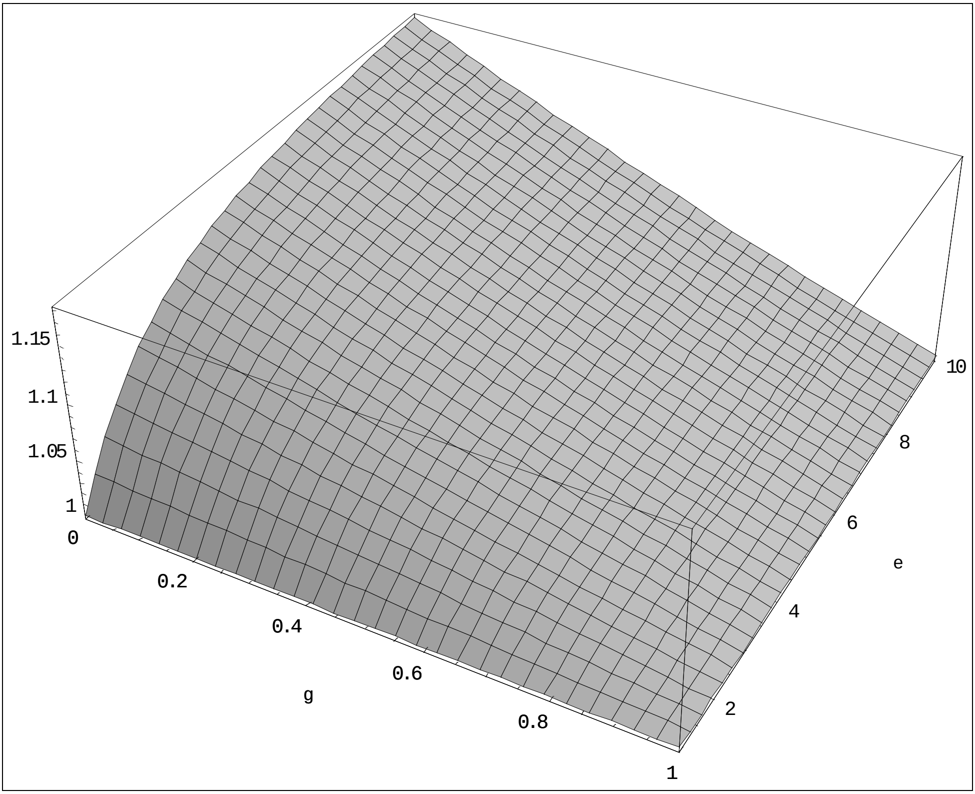

Figure 14 Short-run changes in tradeables price index (Case 3)

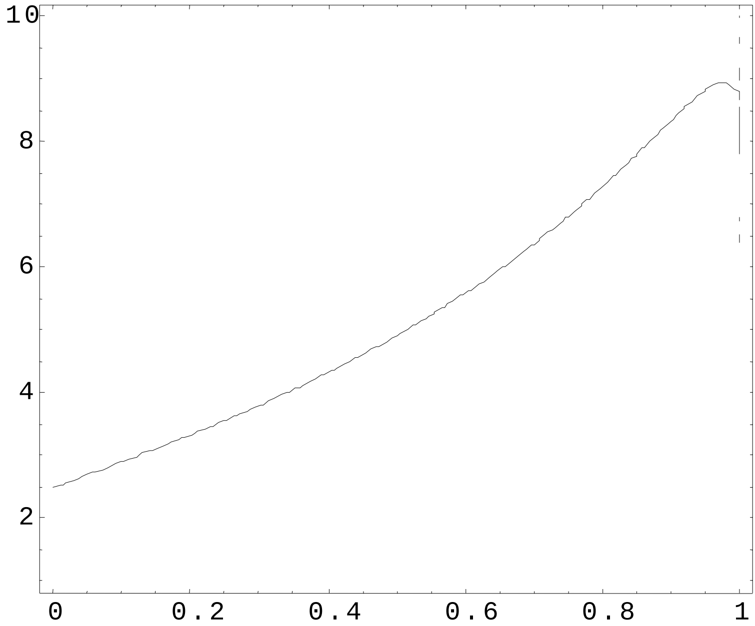

Figure 15 Overshooting region for short-run changes in tradeables price index (Case 1). Overshooting takes place in the region above the line. Corresponds to Figure 4.

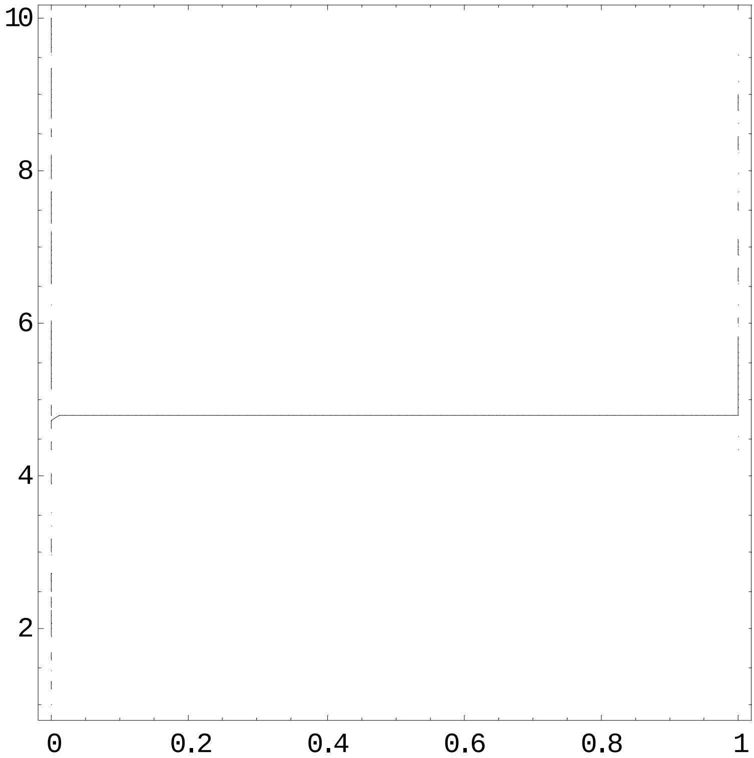

Figure 16 Overshooting region for long-run changes in nontradeables price index (Case 1). Overshooting takes place in the region above the line, where values of • (on vertical axe) are greater than 4.86. Corresponds to Figure 6.

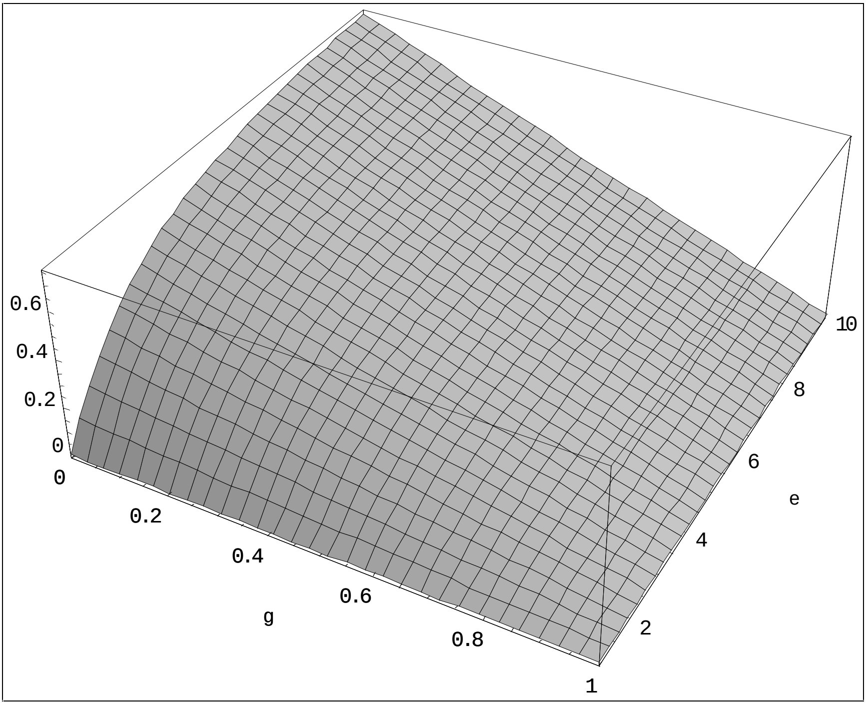

Figure 17 Short-run changes of real foreign money balances (Case 1)

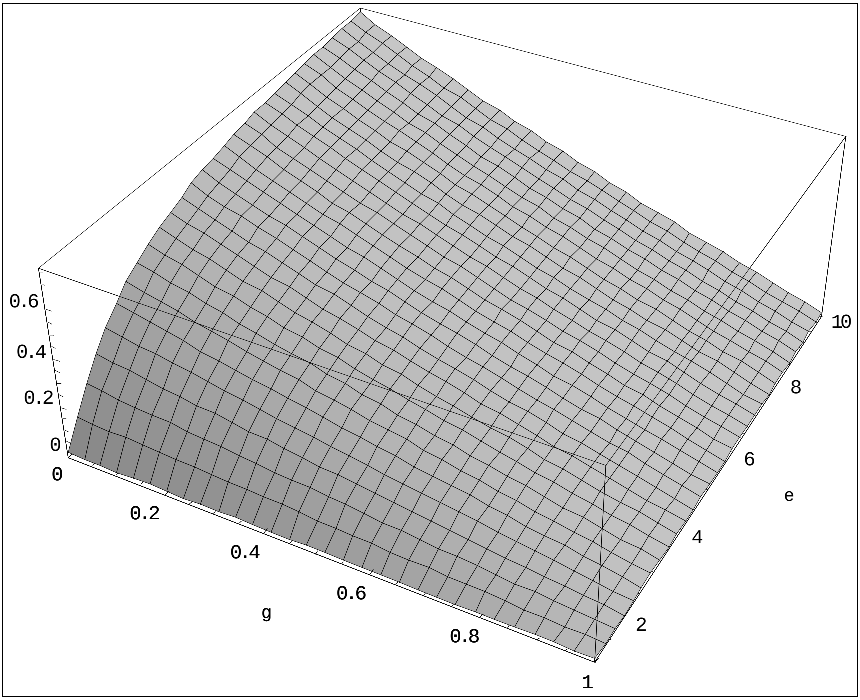

Figure 18 Short-run changes of real foreign money balances (Case 2)

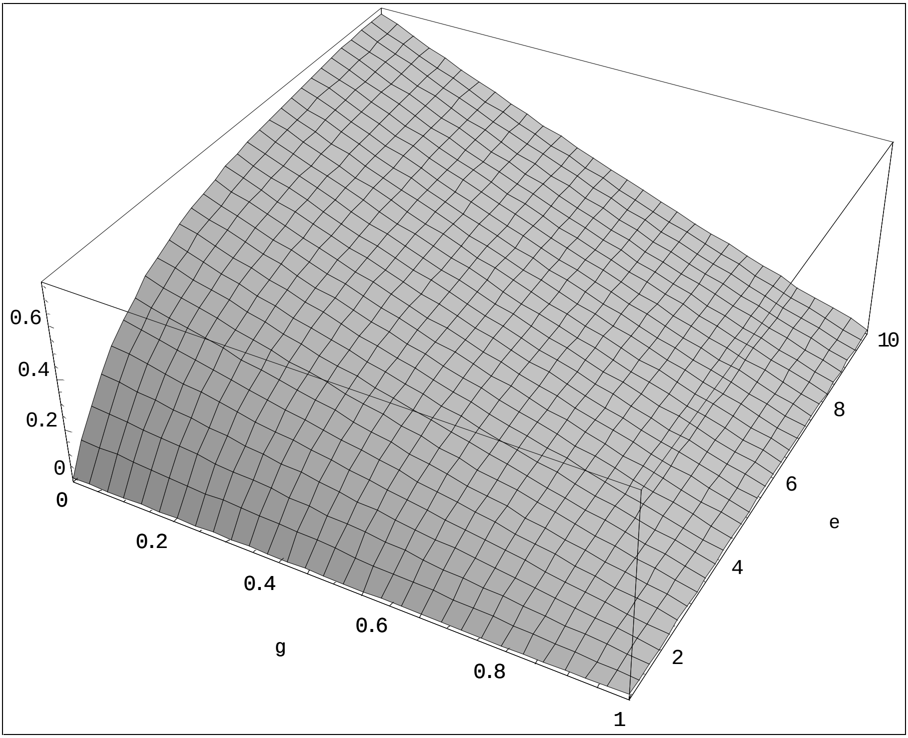

Figure 19 Short-run changes of real foreign money balances (Case 3)

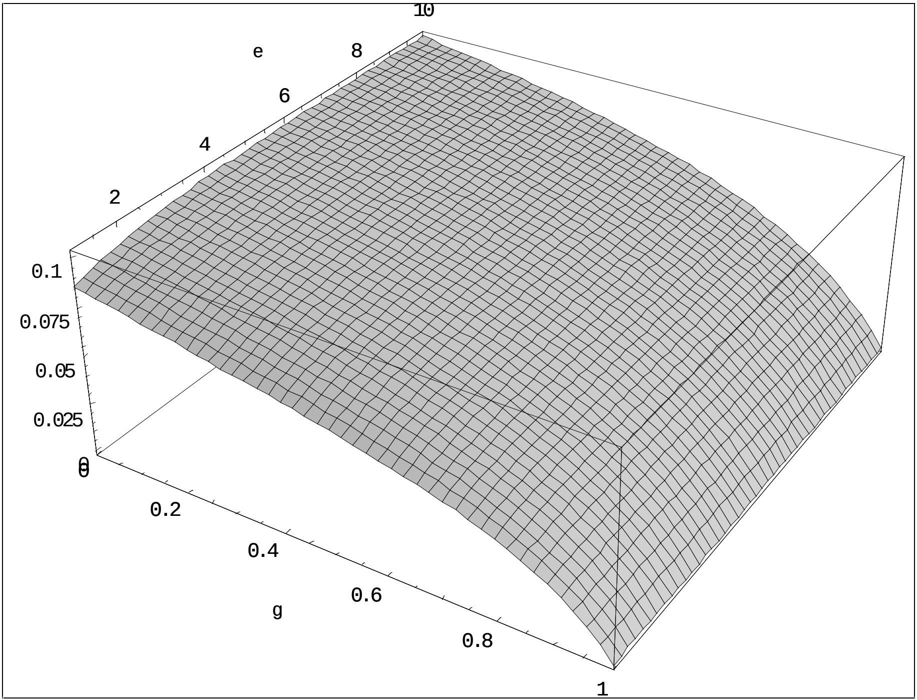

Figure 20 Long-run real exchange rate (Case 1)

Data for transition economies

Table 2 Data for Transition Economies in CEE and Baltics[12]

						CAB in USD million			
Country	**Year inflation peaked**	**Max end –year inflation rate**	**Stabilisation Programme Date**	**Exchange rate regime a dopted at the date of stabilisation**	**Lowest Output**	**Pre Peak Year**	**Peak Year**	**1 Year After**	**CAB[13] Change**
Albania	1992/97	236.6/42.1	Aug-92	Flexible	1992	-168	-51	15	66
Bulgaria	1991/97	338.9/578.6	Feb-91	Flexible	1997	-1152	-842	-1089	-247
Croatia	1993	1149	Oct-93	Fixed	1993	329	104	103	-1
Czech Rep.[14]	1991	52	Jan-91	Fixed	1992	-338	1143	-305	-1448
Estonia	1992	953.5	Jun-92	Fixed	1994		153	40	-113
FYR Macedonia	1992	1935	Jan-94	Fixed	1995	-259	-19	-36	-17
Hungary	1990	33.4	Mar-90	Fixed	1993	na	127	267	140
Latvia	1992	959	Jun-92	Flexible /Fix[15]	1995	na	207	417	210
Lithuania	1992	1161	Jun-92	Flexible /Fix[16]	1994	na	322	-84	-406
Poland	1990	249	Jan-90	Fixed	1991	na	716	-1359	-2075
Romania	1993/97	295.5/151.4	Oct-93	Flexible	1992	-1460	-1170	-428	742
Slovak Re.	1991	58.3	Jan-91	Fixed	1993	-767	-786	173	959
Slovenia	1991	247.1	Feb-92	Flexible	1992	518	129	926	797

[12] Data is from the EBRD Transition Report 1999, Table 3.1, p. 63; and the current account (CAB) section data is from Table 3.6.1, p. 130 of "Economic Survey of Europe in 1995-1996" by the Economic Commission for Europe, Geneva. United Nations, New York and Geneva, 1996.

[13] CAB change is the difference of two previous columns and is equal to the CAB value one year after inflation peak minus the CAB value at the year inflation peaked.

[14] For Czech and Slovak republics, the CAB data is only for convertible currency.

[15] The Latvian currency was pegged to the SDR in February 1994, the currency was flexible prior to this time.

[16] Lithuania adopted a currency board in April 1994, the exchange rate was flexible prior to this time.

Table 3 European Transition Economies in 1998, GDP[17]

Country name	Population, millions	GDP per capita, USD	GDP, millions USD
Albania	3.2	930	2976
Bulgaria	8.3	1315	10914.5
Croatia	4.53	4820	21834.6
Czech Rep	10.3	5479	56433.7
Estonia	1.45	3593	5209.85
FYR Macedonia	2	1548	3096
Hungary	10.1	4730	47773
Latvia	2.4	2622	6292.8
Lithuania	3.7	2890	10693
Poland	**38.7**	3887	**150426.9**
Romania	22.5	1695	38137.5
Slovak Rep	5.4	3793	20482.2
Slovenia	2	**9779**	19558

Note: Values in bold are the highest nominal GDP for Poland and the highest GDP per capita for Slovenia.

[17] Data is from the EBRD Transition Report 1999, Country tables, pp. 183-269.

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