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Documents

Household Behaviour in the MSG-6 Model

1. Introduction

MSG-6 is an Applied General Equilibrium (AGE) model for the Norwegian economy developed at Statistics Norway. As its five predecessors the sixth generation of the MSG model is designed in order to calculate consistent long-run projections. However, the sixth version is in several respects very different from its predecessors. Most of these changes have been motivated by the need for improving the relevance of the model as an analytical tool in policy analyses focusing on effects on welfare and resource allocation. In particular, the model has been designed in order to address issues such as taxation, trade policy, various types of industry subsidies, environmental and energy policies. MSG-6 has become considerably larger and, in several respects, much more complex than MSG-5. Accordingly, there is a need for revising the documentation of MSG-5 given in Holmøy, Nordén and Strøm (1994).

However, a complete documentation of such a large model as MSG-6 is a very time consuming job. From our experiences there is a great risk that further model developments have made the documentation obsolete when it is finally finished. For documenting MSG-6 the team working on the model will therefore follow another approach. Rather than publishing one large all-including documentation, the most important sub models, such as the modelling of consumer and producer behaviour, will be described in separate papers. These papers are intended for readers who are interested in the economics in the model. In addition to such papers, the equation structure will be described accurately but rather technically in a paper intended primarily for readers who are operating the model or have interest in the accurate technical formulations. More general overviews of the model will also be presented in papers presenting results from applied modelling work, see e.g. Bye (1996) and Holmøy and Strøm (1997).

The present note describes the modelling of the household behaviour in MSG-6. It focuses on the intertemporal behaviour and the allocation of time between labour supply and leisure. These aspects of household behaviour were not included in earlier versions of the MSG model. Section 2 describes the theoretical model of individual and aggregate household behaviour. The empirical assessments underlying the quantification of the specified parameters are also included. Section 3 describes the intertemporal budget constraint for the Norwegian economy, and how this effectively constrains household consumption.

2. The theoretical model

Consumption, labour supply and saving result from the decisions of an infinitely lived representative consumer with perfect foresight maximising intertemporal utility. The preference structure is separable, and its nested structure is illustrated in Figure 1 and 2. The purpose of the present note is to present a description of that part of the preference structure which is depicted in Figure 1. We refer to Aasness and Holtsmark (1995) for a documentation of the demand system derived from the part depicted in Figure 2.

Figure 1. The preference structure of households in MSG-6. The two upper nests

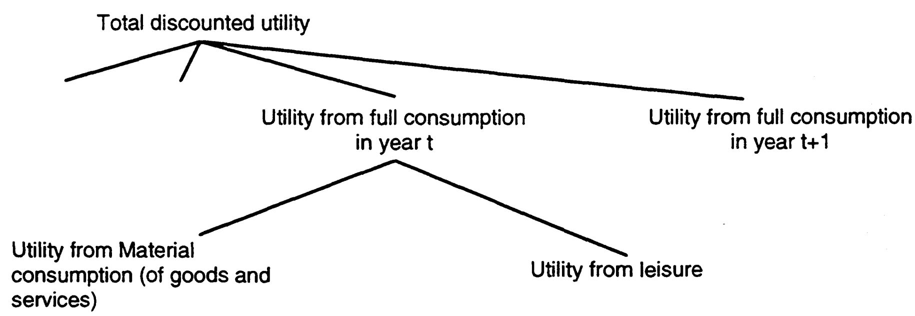
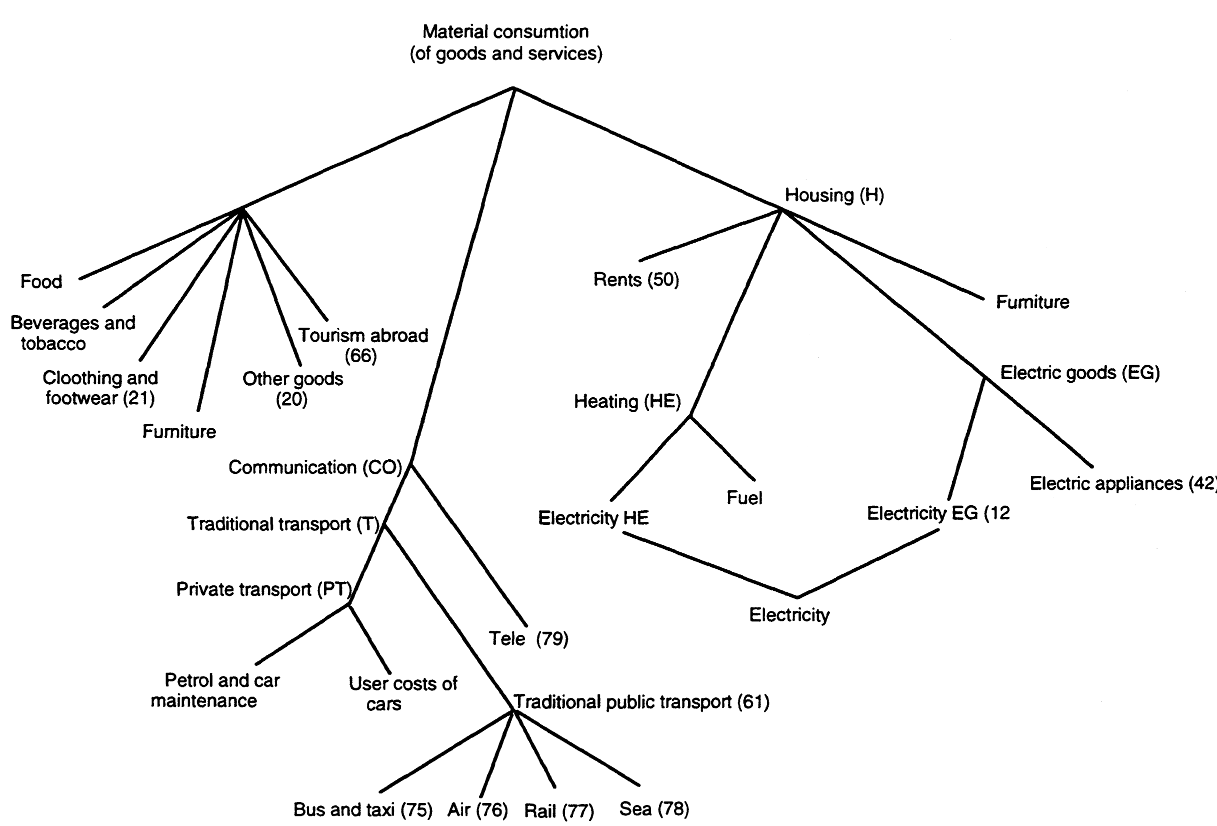


Figure 2. The preference structure of households in MSG-6. The nests in the aggregate *Material Consumption of Goods and Services*



Given the separable preference structure, the consumer can solve his maximisation problem by multi-level budgeting. In year t the representative consumer chooses a path of "full consumption" by maximising the intertemporal additive utility function

$$(1) \qquad U_t = \sum_{s=t}^{\infty} (1+\rho)^{t-s} \left(\frac{\sigma_F}{\sigma_F - 1} \right) F_s^{(\sigma_F - 1)/\sigma_F}$$

subject to an intertemporal budget constraint, which will be described in section 3. U is total discounted utility and F is full consumption at the level of the representative consumer, ρ is the subjective rate of time preference, and σ_F is the intertemporal elasticity of substitution in full consumption.

The individual demand for full consumption following from the utility maximisation, is given by

$$(2) \qquad F = \lambda^{-\sigma_F} \left(\frac{1 + r(1 - t_D)}{1+\rho} \right)^{\sigma_F} PF^{-\sigma_F},$$

where r is the world market interest rate on financial wealth, t_D is the tax rate on capital income, λ is the marginal utility of net wealth and PF is the ideal price index of full consumption. Note that λ will be constant over time, but it is endogeneous in the complete intertemporal model. The value of is the main determinant of the full consumption level and the solution is consistent with a non-Ponzi game condition for the evolution of the net foreign debt. In section 3 we show in more detail how the intertemporal budget constraint is invoked to find the equilibrium value of λ.

σ_F has been set equal to 0.3. This is admittedly a guesstimate, but in accordance with what is typically found in the literature, see Steigum (1993). r is the nominal interest rate facing the consumer. It is related to the exogenous nominal world interest rate by a fixed coefficient. After the tax reform in 1992, t_D equals 0.28.

A necessary and sufficient condition for obtaining a steady state solution for F is that $r(1\text{-}t_D) = \rho$ and that PF is stationary at least in sufficiently many of the last years in the simulation period. ρ has been calibrated according to satisfy this condition. From the calibration of ρ it follows that Equation (2) degenerates to $F = (\lambda \cdot PF)^{-\sigma_F}$, which is the form that has been implemented in the present version of the model.

Full consumption is a CES-composite of (the utility from) material consumption, C, and leisure, LE. The corresponding dual price index is given by

$$(4) \qquad PF = \left[\alpha_C PC^{(1-\sigma_{LC})} + (1-\alpha_C)\, PLE^{(1-\sigma_{LC})} \right]^{1/(1-\sigma_{LC})},$$

which is a CES-function of the price index for material consumption, PC, and the price of leisure measured in efficiency units, PLE. σ_{LC} is the elasticity of substitution between material consumption and leisure. $\sigma_{LC} = 0.25$ based on the econometric work on micro data presented in Aaberge, Dagsvik and Strøm (1995). α_C is the budget share of material consumption in the full consumption expenditure. Our calibration to 1992 figures implies $\alpha_C = 0.49$. However, α_C must be calibrated simultaneously with the calibration of the components in the time budget of the representative consumer, which is described after Equation (13) below.

The price of leisure measured in efficiency units is related to the pre-tax wage rate, W, in the following way:

$$(5) \qquad PLE = \frac{W(1-t_W)}{\varepsilon_L}.$$

W is the average pre-tax wage income received by the wage earners per man hour. t_W is the average marginal tax rate on wage income. ε_L is an exogenous factor used to convert leisure time into efficiency units, which has been normalised to unity in the base year. Growth in ε_L is a way of formulating technical progress in consumption of leisure. In steady state the growth rate of ε_L is equal to the common rate of Harrod-neutral technical change in the industries. In the equations where *PLE* enters MSG-6, it has been normalised to unity in the base year. Consequently, *PLE* is a price index in the same way as the other prices entering the consumer demand system. It measures the change in the price of a unit of leisure defined as the base year value of leisure consumption.

Norway has a progressive tax system for labour income. The *average marginal* tax rate on wage income, t_W, which is the relevant marginal tax rate for the *representative* consumer, would in general not coincide with the maximum marginal tax rate. Rather, the assessment of t_W has been based on computations of the micro simulation model LOTTE, see Arneberg *et al.* (1995). LOTTE computes the marginal tax rate for a representative sample of wage earners, and the relevant income weighted average of these tax rates. From these computations t_W has been set equal to 0.38.

The price of material consumption, *PC*, is the other price in the index formula for *PF*. This is an ideal price index reflecting the minimum expenditure of increasing the subutility level from material consumption by one marginal unit. This marginal unit cost is derived from the linear expenditure system that follows from cost minimisation to a mixed system of non-homothetic Stone-Geary preferences and non-homothetic CES-preferences[1]. This equation system as well as the estimated parameters are described in detail in Aasness and Holtsmark (1995). Note that «marginality» in the definition of the price index refers to an increase in the sub utility level *C* from an initial level that exceeds the minimum quantities specified in the non-homothetic utility functions defining *C*. The presence of minimum quantities implies that the complete expenditure function is additively separable in a fixed cost term associated with purchases of the minimum quantities, and a variable cost term. With the utility functions used in MSG-6 to define *C*, the variable part of the expenditure function is linear in *C*. Formally, the expenditure function associated with obtaining the sub utility level *C* can be written as

$$(6) \qquad E(PC_1, PC_2, \ldots, PC_n) = VC^M + PC \cdot C,$$

where PC_i are the purchaser prices of consumer good i including VAT and other kinds of indirect taxes, and VC^M is the expenditure necessary to buy the exogenous minimum quantities per homogenous adult household member. Formally

$$(7) \qquad VC^M = \sum_{i \in \mathbf{C}} PC_i \gamma_i,$$

[1] The non-homothetic Stone-Geary utility function is an origo adjusted Cobb-Douglas function. Formally, it is written $C = A \cdot (C_1 - \gamma_1)^{\beta 1} \cdots (C_n - \gamma_n)^{\beta n}$, where C_i is the consumed quantity of consumer good i, γ_i is the minimum quantity of consumer good i, and A and the β's are parameters. Non-homothetic CES-preferences is defined analogously as an origo adjusted CES-function.

where γ_i is the exogenous minimum quantity of consumer good i. Note that the consumer prices equal service prices for durable consumption goods. Accordingly, the price- and quantity indexes in the composite of material consumption differ from the corresponding concepts in the national accounts.

Given the focus on the upper nests in the demand system in this exposition, it suffices here to write the price index PC on the general form:

$$(8) \qquad PC = \left(\sum_{i \in C} \beta_i PC_i^{1-\sigma_C} \right)^{1/(1-\sigma_C)},$$

where β_i is the estimated marginal budget share of good i, and σ_C is the substitution parameter in the CES-preference structure of *Material Consumption.*

The definition and interpretation of PC as a unit cost function associated with increases in the sub utility level implies that PF should be interpreted in the same way. This interpretation is important when one wants to apply Shephard's lemma in order to derive demand functions. The optimal input of sub utility from respectively leisure and material consumption per unit of full consumption of the representative consumer, can be found by applying Shephard's lemma to (4).

The consumer econometrics underlying the estimation of the system of aggregate demand for goods within the aggregate *Material Consumption*, distinguishes three homogeneous consumer groups; adults, children and elderly living in institutions, see Aasness and Holtsmark (1995). There are evidence indicating that the representative members of these groups differ systematically with respect to the shape of the utility function. For example children typically obtain the same utility level as an adult at a lower level of material consumption. Although hard to rationalise and quantify, such considerations have generated so-called consumer equivalence scales. In MSG-6 the representative consumer is interpreted as one person in the group of homogeneous adults, so the formulas above refers to the behaviour of such an adult. In order to find aggregate full consumption over all consumers, the average level has to be multiplied by the number of consumers measured in «adult equivalents». To this end we have used the OECD scale of consumer equivalence to convert children and elderly in institutions into such equivalents. Denoting the total number of adult equivalents by N^F, the aggregate level full consumption becomes $F \cdot N^F$.

The corresponding aggregate sub utility levels result after multiplication by $F \cdot N^F$

$$(9) \qquad C = \frac{\partial PF}{\partial PC} F \cdot N^F = \alpha \left(\frac{PC}{PF} \right)^{-\sigma_{LC}} F \cdot N^F$$

$$(10) \quad LE = \frac{\partial PF}{\partial PLE} F \cdot N^F = (1-\alpha) \left(\frac{PLE}{PF} \right)^{-\sigma_{LC}} F \cdot N^F.$$

According to the normalisation of *PLE*, *LE* is a volume index for leisure measured in fixed base year prices.

The utility index of *Material Consumption* satisfies the identity

$$(11) \quad C = \frac{VC - VC^M}{PC},$$

since VC is total expenditure on goods belonging to the aggregate C, which is identical to the level of the expenditure function in (6).

Consumption of the different specified consumer goods (included in *Material Consumption*) is given by

$$(12) \quad C_i = \beta_i \left(\frac{PC_i}{PC}\right)^{-\sigma_c} C + \gamma_I + C_i^E .$$

C_i^E is an exogenous residual determined in the base year as the difference between the observed consumption level of good i and the level determined by the corresponding estimated demand equation.

Individual labour supply follows from the time constraint for the representative consumer. Aggregate labour supply is given by

$$(13) \quad L = (24 - FM)(365 - 104 - 25)NY - LE$$

where NY is the exogenous number of persons in the labour force, including people in the age interval [16 - 65]. FM is the exogenous number of hours out of the twenty-four that is supposed not to be allocated by endogeneous choice between work and leisure. 104 + 25 is the number of days per year which have to be used for recreation (Saturdays + Sundays + legal vacation). When calibrating the model, L and NY is known. Simultaneously with the budget share of leisure, 1 - α_C, FM is calibrated to 15.3 hours. From (13) FM should not be interpreted as an average number over all days, but rather as the number being representative for an ordinary working day.

The parameter values implies that the income effect of an increase in PLE outweighs the substitution effect on the demand for leisure when all non-wage income components are held constant. This implies a backward bending labour supply curve in a wage-labour supply diagram, a property that has been critisised in Håkonsen and Mathiesen (1997). However, this is not true if one takes into account that the non-wage income, regarded as exogenous by the consumer, is endogeneously determined in the complete equilibrium model. As pointed out in Holmøy (1997), a rise in the wage rate has a positive effect on labour supply when general equilibrium effects on non-wage income are taken into account.

The income effect on leisure demand would have been smaller if α_C were larger, that is if the base year allocation of time to leisure were smaller. In this respect it is worth mentioning that our calibrated time share of leisure is negatively biased compared with the most appropriate data reported in the Time Budget Surveys, see Table 1 below. This bias is a price we have paid in order not to end up with a partial labour supply wage elasticity that does not stick out too much compared with estimates adopted in other empirical models for Norway.

Table 1. Average time spent on various activities on Mondays - Thursday by a sample of 3 459 persons from 16 to 79 years of age in 1990-91. Hours and minutes

Income producing work, including journey to work etc.	4.40
Household work and family care	3.29
Education	0.42
Personal needs	9.47
Leisure time	5.15
Other, unknown	0.07
Total	24.00

Source: The Time Budget Surveys, Statistics Norway (1992).

Personal needs is the activity category that corresponds most directly to the variable *FM*. It is seen that the figure following from our calibration, i.e. 15 hours and 20 minutes, is significantly higher than 9.47. In addition, since the Time Budget Surveys includes elderly between 66 and 79 years of age that is not included in the labour force, it is likely that the reported time spent on *Personal Needs* overestimates the time spent on the same activity by members of the labour force. Consequently, our allocation implies that the time available to endogeneous allocation is even smaller compared to what follows from direct calibration to the Time Budget Surveys. The same conclusion holds even if all time spent on household work were accounted in the same category as personal needs. Since the number of hours spent on income producing work is given, our calibration implies a negative bias of the time spent on other activites than income producing work. Even if this alternative is labeled *leisure* in the MSG-6 model, it includes in principle all those categories having the same shadow price as leisure. Recall that in addition to a large value of *FM*, relative to available estimates, the subtraction of all legal vacation, Saturdays and Sundays also contributes to a negative bias of the calibrated time spent on leisure.

We close this section by summarising in Table 2 the values of the parameters entering the block describing the intertemporal behaviour and labour supply of households in MSG-6. For completeness we also list the corresponding names used in the computer programme TROLL, in which MSG-6 has been implemented.

Table 2. Parameters in the household block in MSG-6

Symbol used in the text	Explanation	Value	TROLL name
σ_F	Intertemporal elasticity of substitution between full consumption in different periods of time	0.30	*SIGMAFC*
σ_{LC}	Elasticity of substitution between material consumption and leisure	0.25	*SIGMALC*
t_W	Average marginal tax rate on wage income	0.38	*TMW*
α_C	Budget share of material consumption in the full consumption expenditure	0.49	*ALPHAC.0*
FM	Number of hours out of the twenty-four that is supposed not to be allocated by endogeneous choice between work and leisure	15.30	*HOURSMIN*

3. The intertemporal budget constraint

The intertemporal budget constraint for households equals the present value of consumption expenditure in the current and all future periods to total wealth (current non-human wealth plus the present value of labour income and net transfers). In the model this budget constraint is given in an implicit way. The foreign net wealth of the total economy is not allowed to explode. The domestic economy is divided into three different institutional sectors that may accumulate wealth; Households, the Government and a Corporate Sector including the incorporated companies. The model is solved conditional upon a specific rule for the development of the deficit for the Government sector. Moreover, whether profits are added to the share value through retention or distributed as dividends to the shareholders in the household sector will have no real effects in MSG-6[2]. Consequently, the

[2] The dividend policy affects the effective capital income taxation and thereby the effective user cost of capital. However, this influence has only been captured when the producer calculate the net of tax return from the marginal investment in real capital.

financial policy of the firms, including the distribution of dividends, has been fixed exogenously. It then follows from Walras' law that it is the expenditure of the household sector which is effectively restricted by the economy wide intertemporal budget constraint on net foreign wealth when all markets are in equilibrium. We will therefore explain the nature of this constraint in more detail. We will also show how this constraint is implemented in the model and we provide a brief account of how the solution algorithm works with respect to this particular equilibrium condition.

The intertemporal budget constraint follows from a non-Ponzi game condition for the net foreign debt, which states that the present value of the net foreign debt approaches zero as the time horizon is extended towards infinity. Before we turn to a precise formulation of this condition, we introduce the necessary notation and determinants of the net debt accumulation.

Let B_t denote net foreign debt at the end of period t, and let r_t and Z_t denote the world interest rate and the value of net imports in this period, respectively. (The period equals one calendar year in MSG-6.) Assuming that interest is levied at the end of each period, net foreign debt accumulates according to

(14) $B_t = (1+r_t)B_{t-1} + Z_t$.

Let period 0 be the first period in the MSG-6 simulations. B_{-1} is then predetermined. In period t>0, B_t follows from solving the difference equation in (14)

(15) $B_t = B_{-1} \cdot \prod_{s=0}^{t}(1+r_s) + \sum_{j=0}^{t}\prod_{s=j+1}^{t}(1+r_s)Z_j$.

A solution of the MSG-6 with intertemporal behaviour and perfect foresight, requires that the time paths for all variables eventually become stationary over time[3]. Let r and Z (without subscripts) indicate the stationary levels for r_t and Z_t . We separate the time interval (0,t) into the two sub-intervals (0,n) and (n +1, t), where n is chosen so that the variables are stationary in the last interval. By setting $t = n$, (15) yields the net foreign debt at the end of the non-stationary period. It is convenient to calculate B_t conditional upon B_n :

(16) $B_t = B_n(1+r)^{t+1-n} + Z \cdot \sum_{j=n+1}^{t}(1+r)^{t-j}$.

Let $PB_{-1}(t)$ denote the present value of the net foreign debt at the end of period t discounted back to the end of period -1, which is the same point of time as the *beginning* of period 0. Formally, $PB_{-1}(t)$ is calculated as

(17) $PB_{-1}(t) = B_t \cdot \prod_{s=0}^{t} a_s$,

where $a_s = 1/(1+r_s)$. The Non-Ponzi game condition is

(18) $lim_{t \to \infty} PB_{-1}(t) = 0$.

However, (18) is not an operational form in numerical computations. By utilising equations (14) - (17) we transform (18) into an equivalent but more tractable condition.

[3] It is trivial to extend the analysis to include the case where Z_t grows at a constant rate as long as the growth is not strong enough to violate the Non-Ponzi game condition in (18).

First, we rewrite PB_{-1}

$$(19)\quad PB_{-1}(t) = B_t \cdot \Pi_{s=0}^{t} a_s$$

$$= B_{-1} + \Sigma_{j=0}^{n} Z_j \cdot \Pi_{s=0}^{j} a_s + \left(Z \cdot \Pi_{s=0}^{n} a_s\right) \cdot \Sigma_{j=n+1}^{t} \Pi_{s=n+1}^{j} a$$

$$= B_{-1} + \Sigma_{j=0}^{n} Z_j \cdot \Pi_{s=0}^{j} a_s + \left(Z \cdot \Pi_{s=0}^{n} a_s\right) \cdot \Sigma_{j=n+1}^{t} a^{j-n}.$$

It follows that

$$(20)\quad lim_{t\to\infty} PB_{-1}(t) = B_{-1} + \Sigma_{j=0}^{n} Z_j \cdot \Pi_{s=0}^{j} a_s + \left(Z \cdot \Pi_{s=0}^{n} a_s\right) \cdot lim_{t\to\infty} \Sigma_{j=n+1}^{t} a^{j-n}.$$

$$= B_{-1} + \Sigma_{j=0}^{n} Z_j \cdot \Pi_{s=0}^{j} a_s + \frac{Z}{r} \Pi_{s=0}^{n} a_s,$$

since $lim_{t\to\infty} \Sigma_{j=n+1}^{t} a^{j-n} = 1/(1-a) - 1 = a/(1-a) = 1/r$.

Combining (18) and (20) the Non-Ponzi game condition can therefore equivalently be restated as

$$\left(\frac{1}{\Pi_{s=0}^{n} a_s}\right)\left(B_{-1} + \Sigma_{j=0}^{n} Z_j \cdot \Pi_{s=0}^{j} a_s\right) + \frac{Z}{r} = 0$$

$$\Updownarrow$$

$$B_{-1} \cdot \Pi_{s=0}^{n}\left(1 + r_s\right) + \Sigma_{j=0}^{n} z_j \Pi_{s=j+1}^{n}\left(1 + r_s\right) = -\frac{Z}{r}$$

$$\Updownarrow$$

$$(21)\quad B_n = -\frac{Z}{r},$$

where the right-hand side is equal to the present value at the end of period n of the future flow of net export values. (21) implies that in all periods after stationarity has been achieved, the current account is zero. In other words the interest paid on the net foreign debt in period $t > n$ is exactly equal to the value of the net exports. It is easily verified that (21) is equivalent to

$$(22)\quad B_t = B_{t-1},\ t > n.$$

As one would expect from differentiation of stylised analytical models, simulations on the MSG-6 model show a negative relationship between the constant value of the marginal utility of net wealth, λ, and B_t. The intuition is that a rise in λ implies a lower level of full consumption, which turns out to affect net imports negatively. When net imports in all years decline, the net foreign debt will be lower in any period $t > 0$. The solution algorithm that ensures that the solution of MSG-6 is consistent with (21) (or equivalently (22)) works in the following way:

1. MSG-6 is simulated contingent on a constant but exogenous trial value of λ.

2. A period n is found, after which all variables have become sufficiently close to stationarity. n can be found by a formal test checking the growth rates of all variables. In practice, however, an experienced model user knows the value of n that does not violate the stationarity requirement.

3. The value of B_n calculated by (15) is compared with *-Z/r*. Alternatively, the algorithm tests whether or not $B_n = B_{n+1}$, that is if B_t also has become stationary.

4. If $B_n > -Z/r$, that is if the future trade surpluses is not sufficiently large to pay back the interests and debt accumulated at $t = n$, then λ is increased according to a specific procedure. If $B_n < -Z/r$, then λ is decreased. The corresponding revisions of λ is undertaken if, respectively $B_n < B_{n+1}$, and $B_n > B_{n+1}$.. The algorithm then starts at step 1 again.

5. A solution has been found when $B_n = -Z/r$ or, equivalently, $B_n = B_{n+1}$, by a sufficiently small margin.

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