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LEARNING THROUGH SHORT–RUN MACROECONOMIC FORECASTS IN A MICRO–TO–MACRO MODEL

by

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Learning through short-run macroeconomic

forecasts in a Micro-to-Macro Model

by

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Abstract.

Firms in the (Swedish) Micro-to-Macro Model MOSES learn about their environment through internal adaptive expectations and through short-run external forecasts produced by Statistical Bureaus. The statistical Bureaus apply different macroeconomic models, that they estimate on data generated by MOSES. Firms are learning about their degree of trust in the forecasts of both Statistical Bureaus using Bayesian rules. In our experiments with learning through external forecasts firms are either forced to use only one source of macroeconomic information or allowed to choose between them. With these experiments we can simulate a more or less centrally controlled economy. Experiments demonstrate that the more of variety of sources of information allowed the better macroeconomic performance.

Introduction

The standard learning literature focuses on the justification of the rational expectations hypothesis [Bray (1982); Bray-Savin (1986); Bray-Kreps (1986); Cyert-DeGroot (1974); Fourgeaud-Gourieroux-Pradel (1986); Frydman (1982),(1987); Townsend (1978); see Lindh (1993) for a survey] and uses extremely simple macroeconomic models with linear structures. Rational agents are unfamiliar with some parameters of their environment and learn about them through applying simple statistical rules. For purposes of the following exposition we observe that rational expectations learning is a special case of adaptive learning [Day (1963), Lindh (1993)]. Under certain restrictive assumptions about economic fundamentals statistical learning moves the economy towards a rational expectations equilibrium. Stationarity is present in practically all standard learning models.

This paper examines learning processes within an Experimentally Organized Economy (EOE) [Eliasson (1987), (1990), (1991), (1992)]. The EOE is represented by the Swedish micro-macro simulation model MOSES based on individual firms and characterized by a diversly structured non-linear, non-stationary framework. The model rests on more realistic assumptions about firms and markets than the simple analytical models of the learning literature. It comprises explicit procedures of short-run (quarterly) *adaptive* learning and decision-making by boundedly rational firms, interacting in markets through various adjustment processes. The model is applied for long-run simulation experiments, that in particular show the macroeconomic growth consequences of different behavioral regimes. The MOSES model, described in detail in [Eliasson (1978), (1985), (1991), (1992); Albrecht (1989)], exhibits path-dependent, non-stationary dynamics with typical phases of non-predictable erratic behavior. Therefore it is not learnable by standard statistical methods [Eliasson (1987), (1990), (1991)]. Since the reference economic environment is sufficiently large and heterogeneous to force strong bounded rationality on each individual firm, large parts of the experimentally organized economic environment are unknown to them. Hence, learning in the EOE has to be defined more generally, than in rational expectations literature. An experimentally organized learning process is characterized by an explicit determination of the bounds for explorative and informational capabilities of firms, on the one hand, and by the application of both statistical and non-statistical learning procedures. The latter are represented, for example, by valuation and selection between different sources of information.

The purpose of this paper is to examine an experimentally organized learning process within the framework of MOSES based on *external* informational capabilities. A firm in MOSES is limited by its *internal* competence to form rational expectations or even to learn to be more rational. It does not apply any particular theoretical model of the economy to make inferences about the future, as is the case in rational expectations learning models. However it can use external sources of information, like macroeconomic forecasts.

To set up our learning experiments a number of modifications of MOSES have been made, that we detail below. The basic (current) version of the MOSES model on which these modifications have been done is described in [Albrecht et al.(1989), (1992), Eliasson (1991), (1992), Taymaz (1991)]. Two sources of macroeconomic forecasting have been installed into MOSES. They are based on macromodels reflecting different theoretical views. We call these sources Statistical Bureaus, although one can have in mind research institutes or even (macro-) economic schools making predictions in one way or another about macroeconomic performance.

Statiatical Bureaus produce only short-term (quarterly) forecasts, which are endogeneous in the sense, that they both accumulate and use quarterly data generated by MOSES. Although theoretical macromodels applied by Statistical Bureaus, due to their simplificaitions are more or less inconsistent with MOSES, they are self-learning (about parameters) and adapting to some extent to MOSES during simulation runs.

Firms use macroeconomic forecasts to improve micro-based internal expectations. They accept external expectations of Statistical Bureaus in different, experimentally organized regimes. In one case they are obliged to use only one external source of information. In the other case firms can select between the sources subject to the *a posteriori* relative accuracy of forecasts. This freedom to make choices provides a firm with an additional competence to exploit the complex environment of the MOSES model and to attain higher levels of performance[1].

We are interested in two questions; *first*, how firms accept external forecasts in different regimes and, in particular, to what extent they in fact believe in them? *Second*, how experimentally organized learning influences the (simulated) economic growth of the model economy.

The next two sections show, how expectations of MOSES firms are formed in the basic version and how they are modified in our experiments. Section 4 describes the macromodels, section 5 demonstrates the experimental results. The Appendix explains, how the data base for macromodels is organized and how quarterly forecasts are computed for both macromodels.

2. Expectations of firms in the basic version of MOSES[2].

Firms in the micro-macro model have expectations about prices, nominal wages and sales. They are calculated in each quarter as convex combinations of internal and external expectations:

$$X^e_t = RX'_t + (1-R)X''_t \qquad (1)$$

where X^e_t is the expectation of some economic variable (price, wage, sales) for the quarter t; X''_t and X'_t are external and internal expectations for

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[1] We find it particularly important to study the efficiency characteristics of learning mechanisms in such an economic environment, considering the problems facing the formerly planned economies [see Eliasson (1993)]. One of our experiments with restricted access to external information comes fairly close to what could be called a centrally planned policy regime, while another experiment resembles the pluralistic information sourcing of a market economy.

[2]. This section summarises certain specifications of the MOSES model (see [Eliasson (1978), (1985),(1991)], [Albrecht (1989)] needed to clarify the particular learning mechanisms modified in this paper.

the same quarter. The coefficient of this combination R is an exogenous parameter that can be said to reflect *the degree of trust* in external expectations. In the current version of MOSES it is fixed, identical for all firms and equal to 1/2 (firms are assumed to believe equally in their own experience and in the external information). We will endogenize R in the next section.

External expectations are given exogeneously; they grow at a constant rate.Internal expectations are adaptive. They combine the actual tendency of growth of a variable under consideration with the tendency of its deviations from expected values.

All exogenous parameters used in the expectations block of the model are identical for all firms. They believe in the same exogenous growth rate of external expectations and have identical parameters of internal expectations. The diversity of internal expectations among firms is caused by their heterogeneity and, in particular, by the diversity of actual realizations for each firm (actual wages, sales and prices differ among firms).

Although internal expectations of firms are adaptive, firms do not learn about the parameters of their expectations functions. Experiments with the basic version showed, that individual expectations do not generally converge neither to actual values nor to average expectations. This fact gives hope that different modifications of learning mechanisms in MOSES can reveal ability (or disability) of firms to move the economy towards a rational expectations equilibrium. It then has to be understood, how the unchanged learning behavior of MOSES agents (firms) influences the equilibrium characteristics of the entire economy. It becomes an open question, whether a standard type equilibrium at all exists in the Micro-to-Macro model [see Eliasson (1984), (1985, Cnapter VII), (1991)].

3. Learning about external expectations.

In our modification MOSES firms are learning individually about the degree of trust (= R) they can have in external expectations, that are in turn endogenized.

Suppose that firms look at the parameter R as a stochastic variable, normally distributed with mean R' and variance σ. Firms do not know the mean, but are informed somehow about the variance. Each quarter a realization of R updates their prior estimate of the mean R_t in a Bayesian fashion. The realization of the degree of trust is:

$$R_{(t)} = \frac{X^a_t - X''_t}{X'_t - X''_t} \tag{2}$$

where X^a_t is an actual value of the expectational variable in the quarter t. The posterior mean estimate R_{t+1} is a convex combination of the prior R_t and the realization $R_{(t)}$:

$$R_{t+1} = \frac{h_t}{h_t + \sigma} R_{(t)} + \frac{\sigma}{h_t + \sigma} R_t \tag{3}$$

where h_t is the prior variance of the beliefs updated as:

$$h_{t+1} = \frac{\sigma}{h_t + \sigma} h_t \tag{4}$$

This is an application of the theorem on conjugate normal distributions [De Groot(1970), p.167].

The posterior estimate R_{t+1} is obtained by firms after data from quarter t have been observed, when both internal and external expectations are already known. At the end of this quarter a firm forms expectations for the next quarter with the updated degree of trust in the external forecast:

$$X^e_{t+1} = R_{t+1} X'_{t+1} + (1 - R_{t+1})X''_{t+1} \tag{5}$$

The iterative process (3)-(4) does not guarantee that the degree of trust in the external expectations R_t always belongs to the unit interval [0,1]. For example it can be negative, when the degree of trust realization $R_{(t)}$ is negative and has a large weight in Bayesian updating rule (3), because of the relatively large variance of beliefs h_t. Note that the realization $R_{(t)}$ is negative if and only if an external forecast turn out to be less accurate, than the internal expectation i.e. if one of the two conditions is fulfilled :

$X_{t-1} < X''_{t-1} < X'_{t-1}$ or $X'_{t-1} < X''_{t-1} < X_{t-1}$.

In this case a firm decreases its posterior degree of trust.

The conditional variance of firm's beliefs h_t can be high only at the begining of iterations and is monotonously declining to zero, as it is seen from (4). So the "implausible" estimates for R which are beyond the unit interval can occur only at the outset of experiments, when the precision of firms' knowledge about this parameter is not high.

The only exogenous parameter in the described iterative procedure is σ - the variance of the degree of trust. It was estimated from the basic reference experiment of MOSES and was made identical for all firms. It is approximately equal to 0.3 (we used a sample of 50 randomly chosen firms and analysed the data for 10 quarters).

This estimate of σ is of course very rough, but small variations of this parameter do not have much influence on our experiments. Note, that it would be more realistic to consider the variance σ together with the mean R' as the learning parameter. However we follow in this paper the procedure commonly used in the learning literature and restrict ourself to this most simple case.

4. The Macroeconomic Forecasts of the Statistical Bureaus.

Endogenized external expectations of firms is the other feature added to the MOSES expectations block. Statistical Bureaus (SB) or forecasting institutes gather and process statistical data generated in MOSES simulations and compute short-run (quarterly) macroeconomic forecasts based (for each SB) on a macroeconomic model, reflecting some theoretical view about the economy. We shall consider only two Statistical Bureaus, that work independently of each other and update parameters of their models each quarter on the basis of new macroeconomic data generated by MOSES, applying simple econometric techniques (OLS). It means that the SBs are also learning, but in contrast to firms they do not use micro-level information directly. Both of them apply information about exogenous variables and parameters, including those concerning

Government policy and foreign trade from the MOSES data base and simulated time series.

Statistical Bureaus are making quarterly macroeconomic forecasts about the variables, which are of interest for firms: prices, wages and sales. The forecasted growth rates of sales and of output are supposed to be equal, because, by assumption, both SB ignore changes in firms' inventories. Forecasts of Statistical Bureaus are used by firms instead of exogenous external expectations. Firms are learning about the degree of trust to macroeconomic forecasts, following the Bayesian rule (3)-(4)[3].

We assume, that the SBs differ in their theoretical views about the economy. Both of them recognize market disequilibrium in the short-run. But one believes that only the labor market is imperfect, while another assumes that both labor and product prices are rigid and do not clear the markets. The first macromodel (of SB1) is a standard textbook neoclassical-neokeynesian system. In the second model (of SB2) some behavioral assumptions of textbook models have been modified to be more consistent with the MOSES approach.

4.1 Macromodel of Statistical Bureau 1.

The theoretical assumptions of SB1 about the economy are:

- output prices are market-clearing;
- firms are profit-maximizers;
- adjustments of wages depend on the unemployment level via the Phillips curve and on nominal money growth.

SB1 works out the t th quarter forecast at the end of quarter t-1, when it receives from MOSES all the macroeconomic information, concerning the last period. The forecast is based, in particular, on the information about new capital equipment, created in the quarter t-1. A total volume

[3] One can imagine, that the Bureaus forecast some other economic indicators (e.g. unemployment, investment, the interest rate) for the Government, which applies them in policy making and influences the development of the (MOSES) economy. However we do not consider here this aspect of macroeconomic learning and deal only with the learning of firms.

of real capital is the only macroeconomic aggregate, which is updated by SB *a priori*, i.e. before the simulation run with the model.

The model of SB1 contains three balance equations, two behavioural equations and seven macroeconomic functions.

Balance equations :

$$y_t = C_t + I_t + G_t + S_t \tag{6}$$

$$K_t = (1-\delta)K_{t-1} + I_{t-1} \tag{7}$$

$$M_t/p_t = L(r_t) \tag{8}$$

Behavioural equations :

$$\omega^e_t = \partial F(K_t,L_t)/\partial L_t \tag{9}$$

$$w_t = w_{t-1}(1+\mu_t+f_t(U_t/U^n)) \tag{10}$$

The following notation of variables and parameters is used :

y_t - output (GNP); C_t - consumption of households; I_t - real gross investment; G_t - governement expenditures; S_t - foreign trade balance; K_t - real volume of capital; L_t - labor input; p_t - price index; M_t - nominal supply of money; r_t - real interest rate; ω^e_t, ω_t - expected and actual real wages; w_t - nominal wages; $\mu_t = (M_t - M_{t-1})/M_{t-1}$ - growth rate of money supply; U_t, U^n - rate of unemployment, actual and "normal"; δ - rate of capital depreciation.

All the quantative variables of the model except for the money supply M_t are "real": they are deflated to 1982 prices (base year in all MOSES experiments).

Equation (6) is the market-clearing condition for final output; (7) is the capital accumulation equation; (8) is the supply-demand balance for real money, L(r) describes money demand as a function of the real interest rate, $L'(r) < 0$.

Equation (9) is the first order condition for short-run profit maximization, $F(K_t,L_t)$ - macroeconomic production function; (10) is the wage adjustment equation, which says, that the nominal wage growth rate is equal to the nominal money growth rate plus a term depending via the Phillips curve on the relative unemployment level U_t/U^n.

Macroeconomic functions.

Production function:

$y_t = F(K_t,L_t) = Q_t(1\text{-}\exp(-\gamma L_t/Q_t))$ (11)

where $Q_t = \alpha K_t$ is the capacity level, α - capital efficiency parameter; γ - parameter of the labor productivity for the best technology.

Consumpion function:

$C_t = c\, D_t$, (12)

where $D_t = (\omega_t L_t + r_t K_t + d_t/p_t)(1 - T_h)$ is the real disposable income of households, c - parameter; d_t - nominal divident payments, $d_t = \pi_t - I^0_t$, π_t - total firms' net profit after taxation: $\pi_t = (p_t y_t - w_t L_t - (r_t + \delta)K_t p_t)(1 - T_c)$, T_c - corporate tax rate, I^0_t - net investment, defined below; T_h - personal income tax rate.

Investment function:

$I_t = I^0_t/p_t + \delta K_t$, (13)

where $I^0_t = i\pi_t$ is net investment as a share of net profit, i -parameter.

Foreign trade balance:

$S_t = S_{t-1}[1 + s(p^f_t - p_t(1\text{-}T_f))/p_t(1\text{-}T_f)]$,

where p^f_t - foreign price index, T_f - rate of trade tariff, s - parameter.

Phillips curve :

$f(U_t/U^n) = - a \ln(U_t/U^n)$, a - parameter.

Demand for money :

$L(r_t) = b^0 r^b_t$, b^0, b - parameters.

Real wage expectations function :

$\omega^e_t = \alpha_1\omega_t + \alpha_2\omega_{t-1}$, (14)

where α_1, α_2 - parameters. This is the "model" of firms' expectation about real wages, applied by SB1. It is in some sense similar to the actual models of expectations, used by firms in our modification (2). The bureau understands, that firms do not trust its forecasts completely. Therefore the SB1 expects a firm's expectation to be a linear combination of macroeconomic forecast ω_t and internal expectations. The latter can be represented as a linear combination of past real wages. However SB1 simplifies this "actual" model, taking into account only the observation of the past quarter. The bureau therefore expects, that firms will expect the real wage ω^e_{t+1} to be a linear combination of forecast ω_t and the past quarter value ω_{t-1}.

The exogenous variables of the SB1 macromodel are: M_t, G_t, p^f_t. The exogenous fixed parameters are: δ, T_h, T_c, T_f and U^n. Exogenous variables are calculated by SB1 before each quarter simulation run with its model on the basis of the past quarter MOSES output macro data. Exogenous parameters are taken from the MOSES data base.

The parameters of macroeconomic functions c, i, a, b, b_0, α, α_1, α_2, τ are endogenous. They are estimated each quarter by SB1 using accumulated time series and simple linear regressions for (11)-(14). We did not apply a standard simultaneous estimation technique, since macroeconomic functions are highly non-linear with respect to endogeneous parameters and we had to avoid overloading the PC memory. The estimates of the endogenous parameters are in fact quickly stabilizing in the learning process.

4.2. Macromodel of Statistical Bureau 2.

SB2 differs from SB1 in its view on product prices and the behaviour of firms.In the spirit of MOSES, it assumes that:

- output prices are not flexible enough and the market is cleared by quantative adjustments of supply and demand;
- firms do not maximize profits, rather they are satisfied with "admissible" production plans, guaranteeing an expected profit-margin;
- wage adjustment depends on the growth of money supply and on the increase of employment.

In other respects the macromodel of SB2 is similar to the model of SB1. It contains the same balance equations:

$$y_t = C_t + I_t + G_t + S_t, \tag{15}$$

$$K_t = (1-\delta)K_{t-1} + I_{t-1}, \tag{16}$$

$$M_t/p_t = L(r_t), \tag{17}$$

but another set of behavioral relationships :

$$y_t \geq (\omega_t/(1-h^e_t))L_t \tag{18}$$

$$w_t = w_{t-1}(1 + \mu_t + \beta\max(0, (L_t-L_{t-1})/L_{t-1})) \tag{19}$$

$$p_t = p_{t-1}(1 + \lambda Z^*_{t-1}(K_t)/y^*_{t-1}(K_t)) \tag{20}$$

A new variable here is h^e_t in (18) - the expected profit-margin target (see MOSES literature, e.g.[Albrecht (1989), Eliasson (1978),(1991)]). Inequality (18) determines a satisfactory zone in the plane of labor-output production plans. Together with the production function (11) it forms a feasible set of plans as it is the case in the basic version of MOSES.

Equation (19) is a wage adjustment rule, similar to (10). But instead of the Phillips curve it involves the growth rate of employment, β - is an adjustment parameter. According to (19) more employment increases the nominal wage, while additional unemployment does not influence it. This hypothesis reflects the process of labour search and competetive biddings in the labour market, explicitly occurring in MOSES simulation runs.

Equation (20) describes quarterly adjustment of prices, λ is a parameter. $Z^*_{t-1}(K_t)$ denotes an excess aggregate demand of quarter t-1 as a function of capital K_t invested up to the quarter t. Similary $y^*_{t-1}(K_t)$ denotes an output which could be realized in a previous quarter with the same capital K_t and the same other variables.

Adjustment of price (20) is assumed by SB2 to be *prior* to the market-clearing quantative interactions of firms, but *posterior* to the creation of new capital, disturbing the equilibrium, reached in the past quarter. Such disturbance of the past quarter equilibrium is expressed by the right-hand side of (20). Variables K_t and p_t are predetermined in quarterly compytations according to equations (16) and (20).

Macroeconomic functions, applied in the model of SB2 are the same, as in the model of SB1, except for:

The profit-margin expectations function:

$$h^e_t = \lambda_1 h_t + \lambda_2 h_{t-1}, \tag{21}$$

λ_1, λ_2 are parameters.

The profit-margin target is assumed to be determined by the current interest rate:

$$h_t = (\delta + r_t)\, K_t/y_t, \tag{22}$$

This means that the targeted profit-margin is equal to the ratio between real charges on capital account and output.

All exogenous variables and parameters in this model are identical to those explained above. Endogenous parameters are also the same with the exception of β and λ from the wage and price adjustment equations (19), (20) and parameters λ_1, λ_2 in the expectations function (21). Thus, although both Statistical Bureaus use basically the same set of parameters with identical estimates, they apply different theoretical assumptions and models, and therefore produce different forecasts.

5. Experiments and experimental results.

Both SB use synthetic macro-data from the MOSES data base (see Appendix 1). At the beginning of a quarter the bureaus receive information about related variables from the macro-data base and simulate (in a sense) the quarterly iteration of MOSES. They compute a set of macroeconomic aggregates and give quarterly macro forecasts for macro output prices, wages and sales.

The macromodel of SB1 is reduced to a two-dimensional system of equations for nominal and real wages, given the amount of capital created in the (MOSES) economy up to the current quarter. The macromodel of SB2 is solved with respect to output and the nominal wage, given the same macro-data on capital and the current price computed according to the adjustment equation (20). Iterative procedures of equilibrium search for macromodels are explained in Appendixes 2-3.

Both macromodels are quick in finding equilibrium points by these iterative procedures. On the average it takes only ten iterations for both models to reach an equilibrium with an error 1.5%. We computed it with the error smaller than 10^{-5}, which required 40 iterations on the average.

The results of our 120 - quarter simulation runs are shown graphically in Figures 1 - 10. In the first series of experiments firms do not use macroeconomic forecasts. Both macromodels were tested for their predictive ability. From our view both macromodels satisfactorily predicted growth rates of macroeconomic aggregates. One can compare MOSES generated and forecasted trajectories for GNP growth rates in Figures 1 (for SB1) and 2 (for SB2). The average deviation of GNP growth rates is

2.3% to GNP for the model of SB1 and 1.6% to GNP for the model of SB2.

The trajectories in Figures 1 - 2 reveal the particular pattern of forecasting, adopted by each bureau. One can see, that SB1 is in some sense smoothing the actual dynamics, while SB2 tries to imitate it with one-quarter delays. This fact in particular explains the larger deviation for SB1 than for SB2.

In the second series of experiments firms use the forecast of one of the SBs. They apply the Bayesian rule (3)-(4) to determine the degrees of trust in it. Experiments in this regime give the opportuhity to study the accuracy of the SB forecasts once more (learning of firms changes the accuracy of forecasts) and to examine the impact of learning on the dynamics of the economy when firms have only one external source of macroeconomic information - SB1 or SB2.

The accuracy of GNP forecasting of both SBs improves when firms are learning of and using the information produced by the Bureaus in their decisions). When each of them is the only external source of macroeconomic forecasts, the average error in forecasted GNP growth rates is 1.6% for SB1 and 1.4% for SB2. This means that the Bureaus influence the dynamics of MOSES, making firms to adapt to their forecasts.

Figures 3 - 5 expose the dynamics of the (arithmetical) average degree of trust in the macroeconomic forecasts for both SB. They are increasing in time for all expectational variables except for the case of sales, when the average degree of trust in SB1 forecasts is somewhat decreasing at the end of the simulation period. The time paths of average degrees of trust are similar and close to each other for both SB (especially for the case of prices and wages). It means that firms, being restricted artificially to use only one source of external information, on average adapt to it and utilise macroeconomic forecasts in increasing extent.

Learning of firms in such an experimental regime, however, negatively influences macro economic growth. Figure 6 shows GNP growth slowing down compared with the basic (without learning) simulation path. This decline is especially notable towards the end of the simulation. This effect should be explained in the following way. In the basic version of MOSES external expectations of firms are growing exponentially and the degree of trust in them is fixed and equal to 1/2 (see Section 2). This means that all firms partially believe in a macromodel of stationary growth. These optimistic beliefes are partially self-fulfilling, since firms are adjusting to them in short-run planning iterations. Meanwhile the forecasts of both Statistical Bureaus are non-exponential and do not give sufficiently strong signals to firms to increase output plans.

In the third series of experiments firms were allowed to select between the two sources of external macroeconomic information. We used a very simple selection rule. Suppose a firm can *a posteriori* compare the relative accuracy for forecasts of both SB in quarter t and choose which forecast is better to apply in the quarter t+1. For each expectational variable the firm selects the SB with higher *a posteriori* degree of trust R_{t+1} and uses only its forecast in the quarter t+1. This selective rule means, that the firm singles out a forecast of one bureau, which it currently trusts more, and ignores the forecast of the other, keeping the latter in memory until the next updating of degrees of trust and selection of forecasts. The forecast chosen in the quarter t is weighted by the firm's degree of trust in it (R_{t+1}) and provides (in combination with an internal expectation) a next quarter expectation (5).

The experiments with this selection rule showed, that the average degrees of trust in macroeconomic forecasts typically are not monotonously increasing time paths (see Figures (7)-(9) and compare them to (3)-(5)). This is especially notable for the case of sales (Figure (9)). Firms, that are learning simultaneously from both SB and selecting between forecasts, do not adapt to them to such an extent, as is the case, when only one source of external information is allowed. In that case forecasts of one SB or the other could more easily be self-fulfilling, since firms did not change the source of external information in the course of simulation runs.

Experiments displayed the macro economic effects of diversity of information and the information-selection mechanism on macroeconomic performance. Compared to the case, when firms are allowed to use only one SB as information source, economic growth accelerates in the long-run when forecasts of both Statistical Bureaus can be used as information sources (to see this compare Figures 10 and 6); GNP growth in the case of information-selection is in fact even higher than in the basic version of MOSES, where all firms "believed" in their own adaptive forecasting formula and an exogeneus trend belief corresponding to a"theory" of stationary growth. The intuitive explanation to this result is as follows. When there are two or more sources of external information, firms are not tied too much to some particular pattern of forecasting, when forming expectations and choosing production plans. Thus even the simple selection rule applied in our experiments allows firms "to create" in a sense their own, macro-based synthetic models of economic development and to increase the long-run efficiency.

Concluding remarks.

We examined the learning behavior of boundedly rational firms via their internal experience and macroeconomic forecasting of boundedly rational Statistical Bureaus. Our simulations can be considered as an experimental study of different learning regimes with the help of a micro-macro model.

In particular we were interested in the role of the diversity of macro-based external information used by firms in expectations formation. Macroeconomic performance is demonstrated in simulation experiments to be sensitive with respect to choice of learning regime. If all firms have no choice between external forecasts, or their beliefes about the macroeconomic development are homogeneous (as it is the case in the basic version of MOSES), then economic growth can be seen to slow down. But even the simple selection rule between two sources of macro-based forecasts improves economic growth in the long-run. In this case firms, that are initially do not know any theoretical model of the economy, are able to "create" implicitly synthetic macromodels, based on the accumulated selected knowledge.

Appendix 1. Data base for macromodels.

Since both Statistical Bureaus are using macrodata, generated by the micro-macro model, they are, first, accumulating time series of observations to update in each quarter parameters of macroeconomic functions. Second, they utilize the data necessary for quarterly updating of exogenous and predetermined variables. Some of these variables are taken directly from the MOSES data-base [Albrecht (1989), (1992)] and some - are estimated indirectly. Table 1 contains the list of exogeneous and predetermined variables and fixed (non-updated in simulation) parameters. Exogenous variables: money supply M_t and government expenditures G_t are extrapolated by both SB with the help of simple autoregressions $M_t = (1+\mu)M_{t-1}$, $G_t = (1+g)G_{t-1}$; μ, g - parameters of growth rates, updated each quarter. Both SB are using the estimates for money supply growth rate μ_t as the parameter in the wage adjustment equations (2.5) and (2.23).

Table 1.

Macro-variables and parameters	Symbol in our models	Symbol in MOSES code [13]	Method of calculation
Output (GNP)	Y_t	QGNPFIX	Summing up for ten sectors
Consumption	C_t	QSP	Summing up for ten sectors and deflating with endogenously determined price index
Investment	I_t	QINV QINVIN QINVG	Summing QINV for manufacturing sectors with QINVG

Macro-variables and parameters	Symbol in our models	Symbol in MOSES code	Method of calculation
		QINVBLD	QINVIN and QINVBLD
Price index	p_t	QGNPCUR QGNPFIX	The ratio of GNP in current prices to GNP in 1982 prices QGNPCUR/QGNPFIX
Nominal wage	w_t	QW	Average nominal wage weighted by the share of employees
Foreign trade balance	S_t	QEXPORT QIMPORT	Subtracting of the total import (for ten sectors) from the total export (for the same sectors)
Foreign price index	${p^f}_t$	QPFOR QDPFOR	Weighted (by the share of export) average foreign price for four sectors divided by the foreign price of 1982*)
Money supply	M_t	MONEY	Taken without any change
Government Expenditures	G_t	QPURCHG QWSG	Summing up the government wage sum QWSG with government purchases for ten sectors
Interest rate	r_t	RI	Taken without any change
Unemployment	U_t	RU	"-"-"-"-"-"-"-"-"-"-"
"Normal"level of unemployment	U^n	-	Taken equal to the unemployment level of the base year

Macro-variables and parameters	Symbol in our models	Symbol in MOSES code	Method of calculation
Depreciation rate	δ	RHO	Taken without any change
Corporate tax rate	T_c	TXC	"-"-"-"-"-"-"-"-"-"
Personal income-tax rate	T_p	TXC	"-"-"-"-"-"-"-"-"-"
Value-added tax rate	T_f	TXC	"-"-"-"-"-"-"-"-"-"

*) An absolute value of the foreign price for 1982 is computed in a following way. First, the average yearly growth rate of the foreign price δ_f is found. Then an absolute value of this price for 1990 that is known from the MOSES data-base, is divided by $(1+\delta_f)^8$.

Appendix 2. Quarterly computations for the macromodel of SB1.

First of all an amount of capital for quarter t is calculated according to (7) and from MOSES data, related to quarter t-1.

The macromodel, described in the subsection 4.1, is reduced to a two-dimensional system for nominal and real wages: ω_t and w_t given a new amount of capital K_t as the parameter. The first-order condition (9) for the production function (11) is:

$$\omega^e_t = \gamma \exp(-\gamma L_t/Q_t), \qquad (A.1)$$

that determines short-run employment and output:

$$L_t = - \ln(\omega^e_t/\gamma)Q_t/\gamma \qquad (A.2)$$

$$y_t = Q_t(1-\omega^e_t/\gamma) \qquad (A.3)$$

From (8) the real equilibrium interest rate is a function of the real money supply:

$$r_t = L^{-1}(M_t/p_t) \qquad (A.4)$$

Inserting (A.2)-(A.4) in the macroeconomic functions (12) - (13) and taking into account the expectations function (14) and the identity: $\omega_t = w_t/p_t$, we get the balance equation (6) of the form

$$Z_t(\omega_t,w_t) = 0 \tag{A.5}$$

where $Z_t(\omega_t,w_t) = C_t + I_t + G_t + S_t - y_t$ is excess demand as a function of real and nominal wages. Similary, the wage adjustment equation (10) is transformed into :

$$w_t = w_{t-1}(1+\mu_t+f(h_t(\omega_t)/U^n)), \tag{A.6}$$

where $h_t(\omega_t)$ is unemplyment as a function of the real wage (from (14) and (A.2)).

So (A.5) - (A.6) is a two-dimensional system, which is to be solved with respect to real and nominal wages. An iterative procedure given the initial point $\omega^0_t = \omega_{t-1}$, $w^0_t = w_{t-1}$ runs as follows.

$$\omega^i_t = \omega^{i-1}_t - \rho_{1t}Z_t(\omega^{i-1}_t, w^{i-1}_t), \tag{A.7}$$

$$w^i_t = w_{t-1}(1+\mu_t+f(h_t(\omega^i_t)/U^n)), \tag{A.8}$$

where i is a number of iterations, $i=1...i^*$, ρ_{1t} is the damping parameter, which is decreasing when ω_t^i begins to fluctuate. Iterations (A.7) - (A.8) are repeated i^* times, until $\omega_t^{i^*}$ becomes sufficiently close to ω_t^{i-1}:

$$|\omega^i_t - \omega^{i-1}_t|/\omega^{i-1}_t < \epsilon,$$

where ϵ is the error of search.

Then the procedure is stopped and the solution of (A.5) - (A.6) is accepted as $\omega_t = \omega_t^{i^*}$, $w_t = w_t^{i^*}$.

Finally SB1 computes the price p_t simply as $p_t = w_t/\omega_t$, the expected real wage ω^e_t according to (14) and output from (A.3). The triplet of growth rates for the variables (p_t, w_t, y_t) forms the macroeconomic forecast of SB1 for the quarter t.

Appendix 3. Quarterly computations for the model of SB2.

Capital is reestimated according to (16) and data from MOSES. The price is then adjusted for the disturbance of market equilibrium, induced by investment in quarter t-1 (20). Thus capital K_t and price p_t are predetermined at the beginning of the iterative search for an equilibrium.

The model is now solved with respect to two variables: output y_t and the nominal wage w_t by reducing to a two-dimensional system of equations. Let us suppose at the beginning that inequality (18) is not binding in equilibrium (see Figure A.1). Employment can then be expressed as a function of output (and the capital K_t as a parameter) from the production function (11):

$$L_t = - Q_t \ln(1 - y_t/Q_t)\gamma \qquad \text{(A.9)}$$

and is inserted via consumption and investment functions (12) - (13) into demand side of the balance equation (15), which takes the form:

$$z_t(y_t,w_t) = 0, \qquad \text{(A.10)}$$

where $z_t(y_t,w_t)$ expresses an aggregate excess demand as a function of output and the nominal wage. Together with the wage adjustment equation (19), which is slightly transformed:

$$w_t = w_{t-1}[1 + \mu_t + \beta \max(0, H_t(y_t))], \qquad \text{(A.11)}$$

[$H_t(y_t)$ - growth rate of employment as a function of output (from (A.9))], equation (A.10) forms a system to be solved by the following iterative algorithm.

The initial point for it is $y^0_t = y_{t-1}$ $w^0_t = w_{t-1}$. An iterative procedure is similar to (A.7) - (A.8):

$$y^i_t = y^{i-1}_t - \rho_{2t} z_t(y^{i-1}_t, w^{i-1}_t) \qquad \text{(A.12)}$$

$$w^i_t = w_{t-1}[1 + \mu_t + \beta \max(0, H_t(y^i_t))], \qquad \text{(A.13)}$$

where i is the number of iteration, ρ_{2t} - is a damping parameter decreasing with fluctuations of y^i_t.

Iterations (A.12) -(A.13) are stopped, when y^i_t is sufficiently close to y^{i-1}_t:

$$|y^i_t - y^{i-1}_t| / y^{i-1}_t < \epsilon$$

and the solution for (A.10) - (A.11) is taken as $y_t = y_t^{i^*}$, $w_t = w_t^{i^*}$, where i^* is the stopping number.

To deal with the profit-margin target inequality (18) the minimum condition for the employment is used:

$$L_t = \min [-Q_t \ln(1 - y_t/Q_t)\gamma, L^\circ_t(y_t,w_t)]$$

where $L^\circ_t(y_t,w_t)$ is the solution for the equation :

$$(\omega_t/(1-h^e_t))L_t = Q_t[1 - \exp(-\gamma L_t/Q_t)]$$

These equations cannot be solved analytically, so the value of $L^{\circ}_{t}(y_t)$ is computed numerically in each step, when $L_t = L^{\circ}_{t}(y_t)$ in equilibrium.

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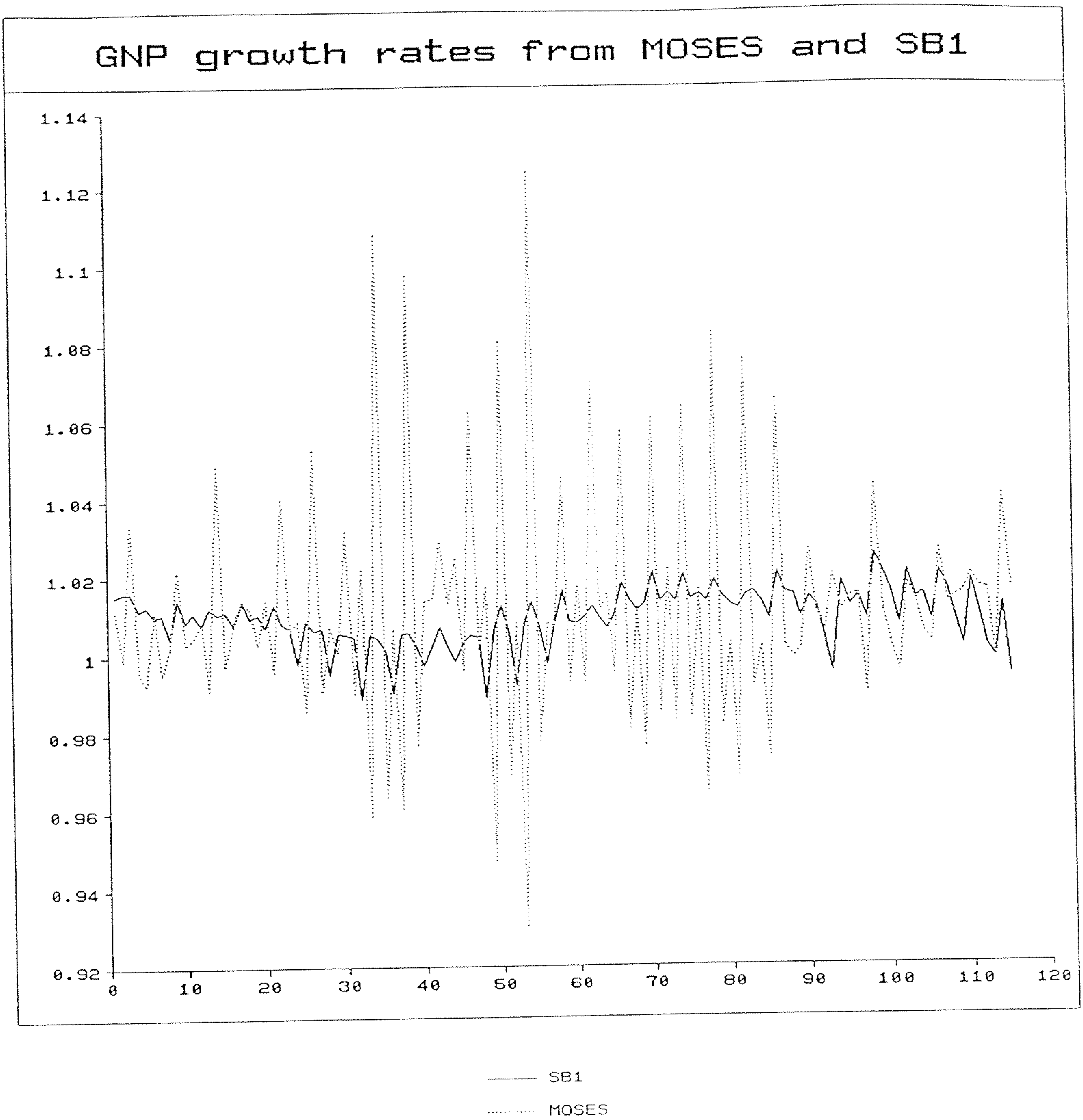
GNP growth rates from MOSES and SB1
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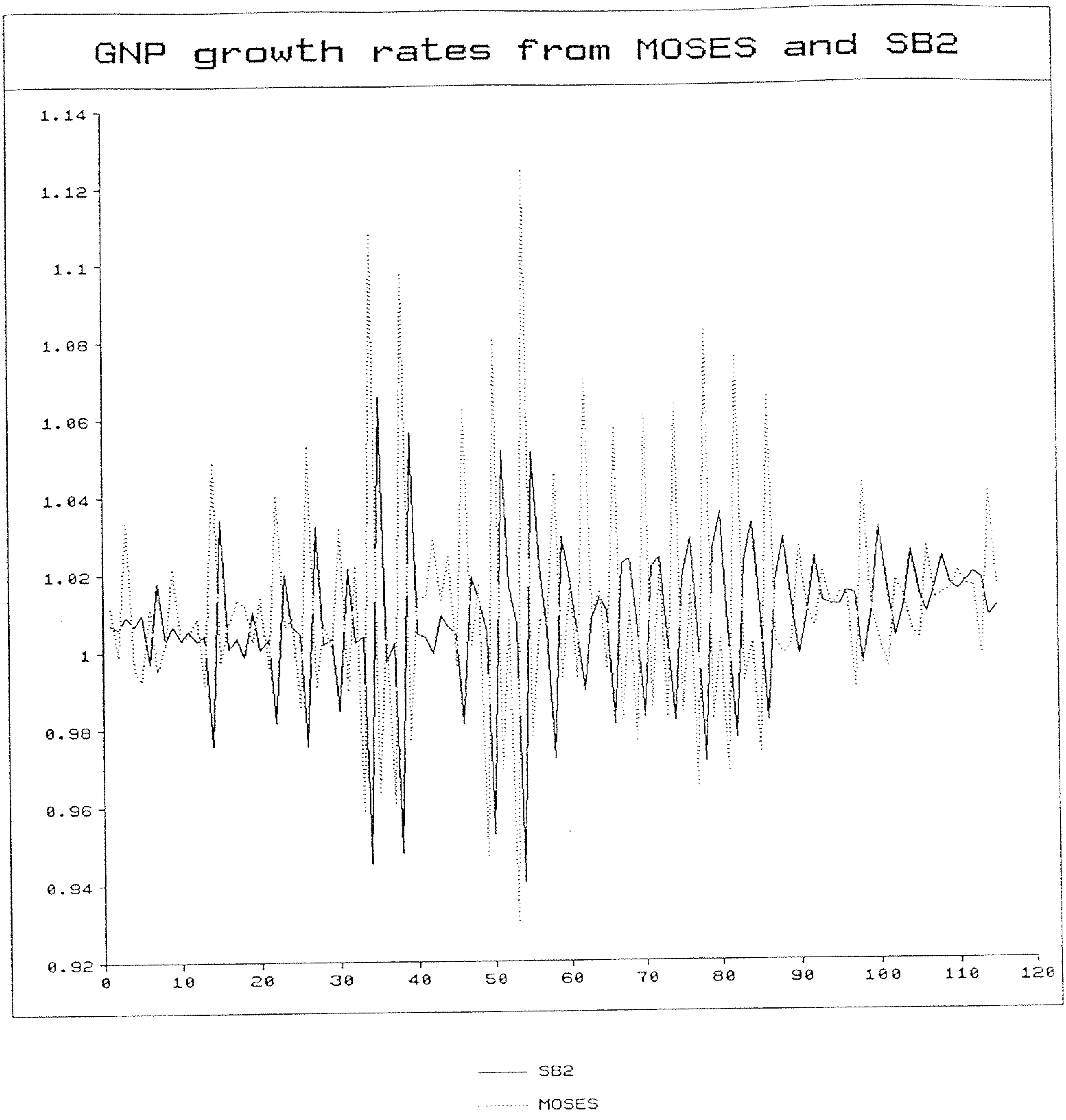
1.12
1.1
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0
10
20
30
40
50
60
70
80
90
100
110
120
SB1
MOSES

Figure 1.


GNP growth rates from MOSES and SB2
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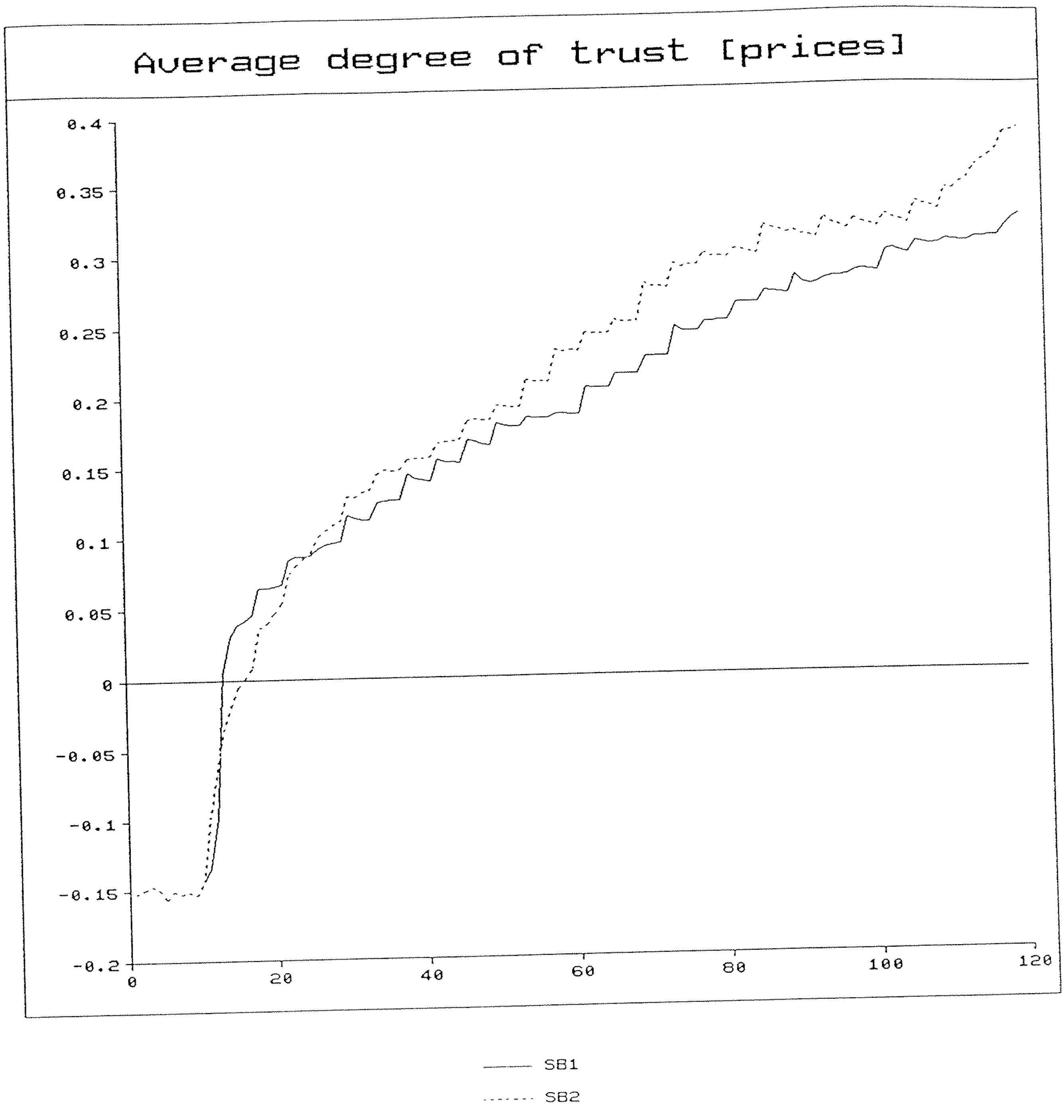
1
0.98
0.96
0.94
0.92
0
10
20
30
40
50
60
70
80
90
100
110
120
SB2
MOSES

Figure 2.


Average degree of trust [prices]
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0.3
0.25
0.2
0.15
0.1
0.05
0
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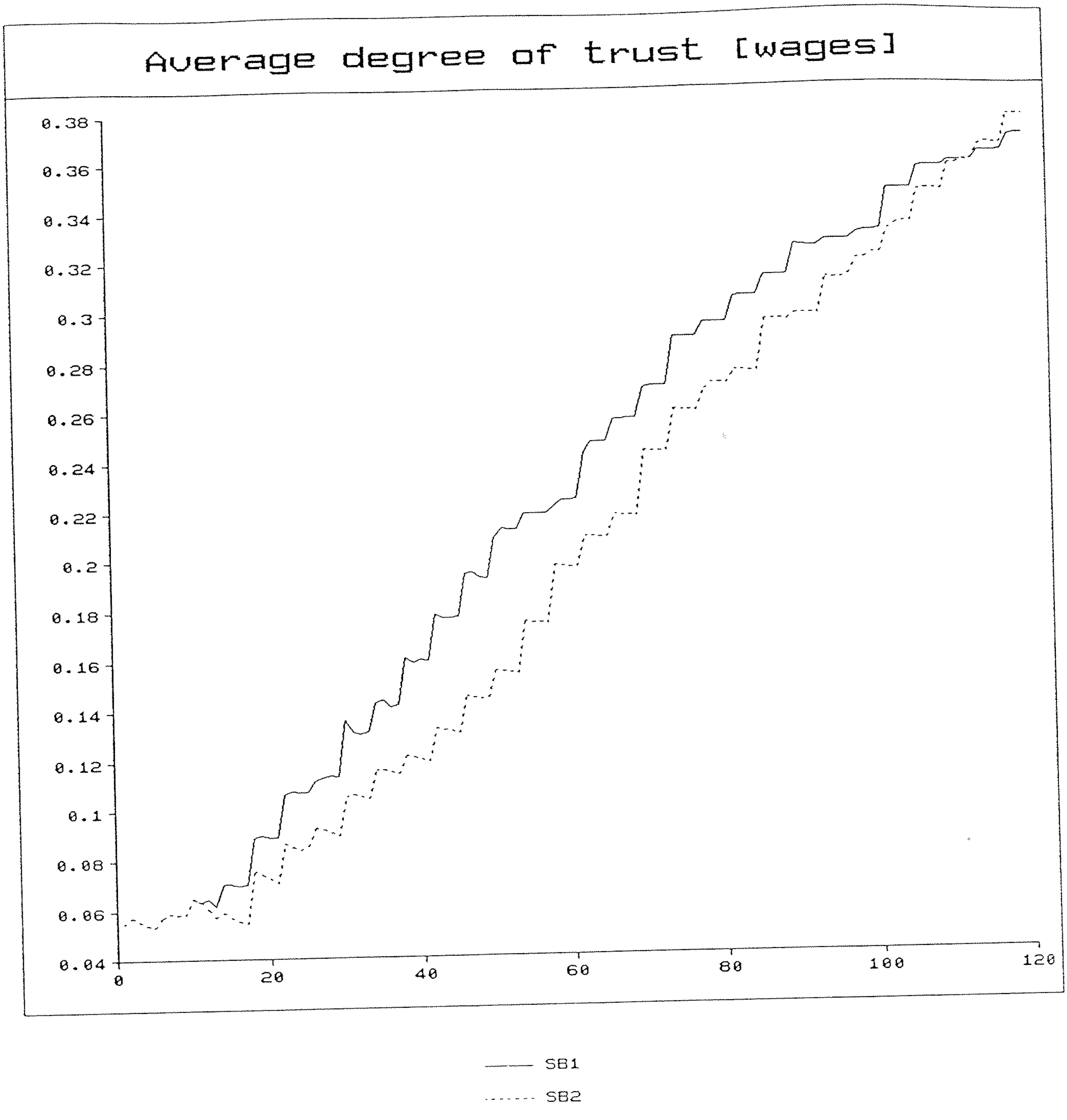
-0.15
-0.2
0
20
40
60
80
100
120
SB1
SB2

Figure 3.


Average degree of trust [wages]
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0.34
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0.18
0.16
0.14
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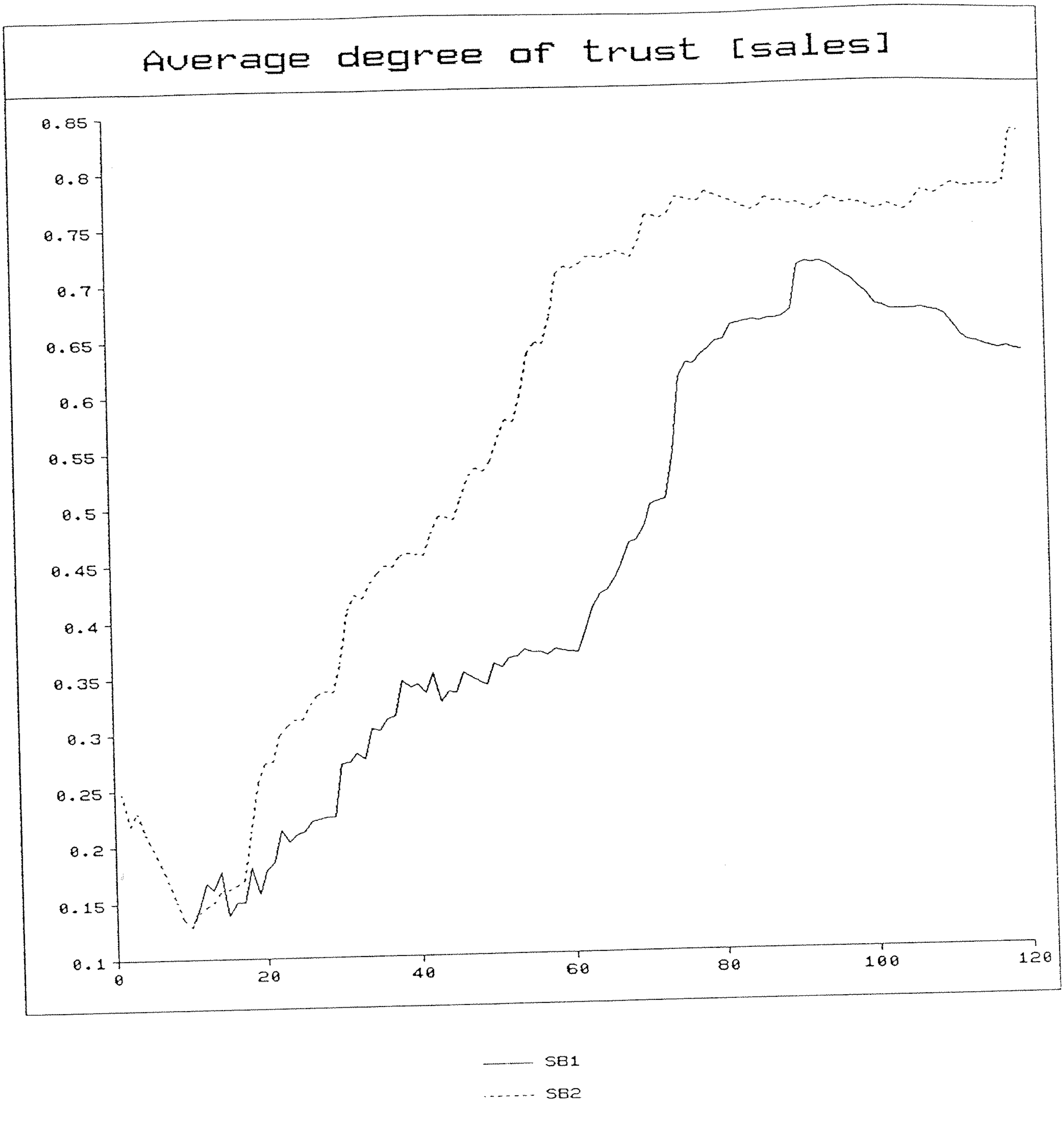
0.06
0.04
0
20
40
60
80
100
120
SB1
SB2

Figure 4.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0.35
0.3
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0.2
0.15
0.1
0
20
40
60
80
100
120
SB1
SB2

Figure 5.

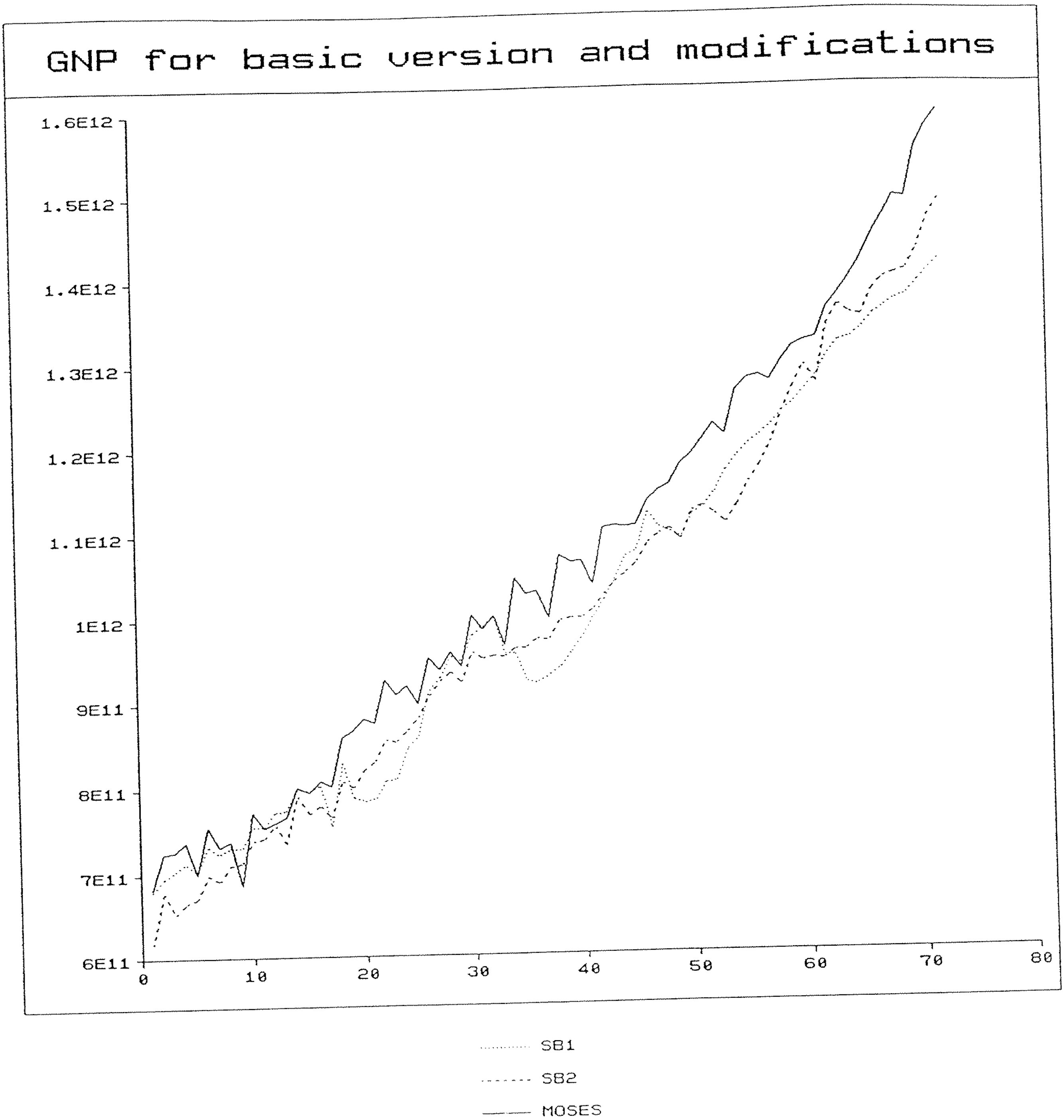
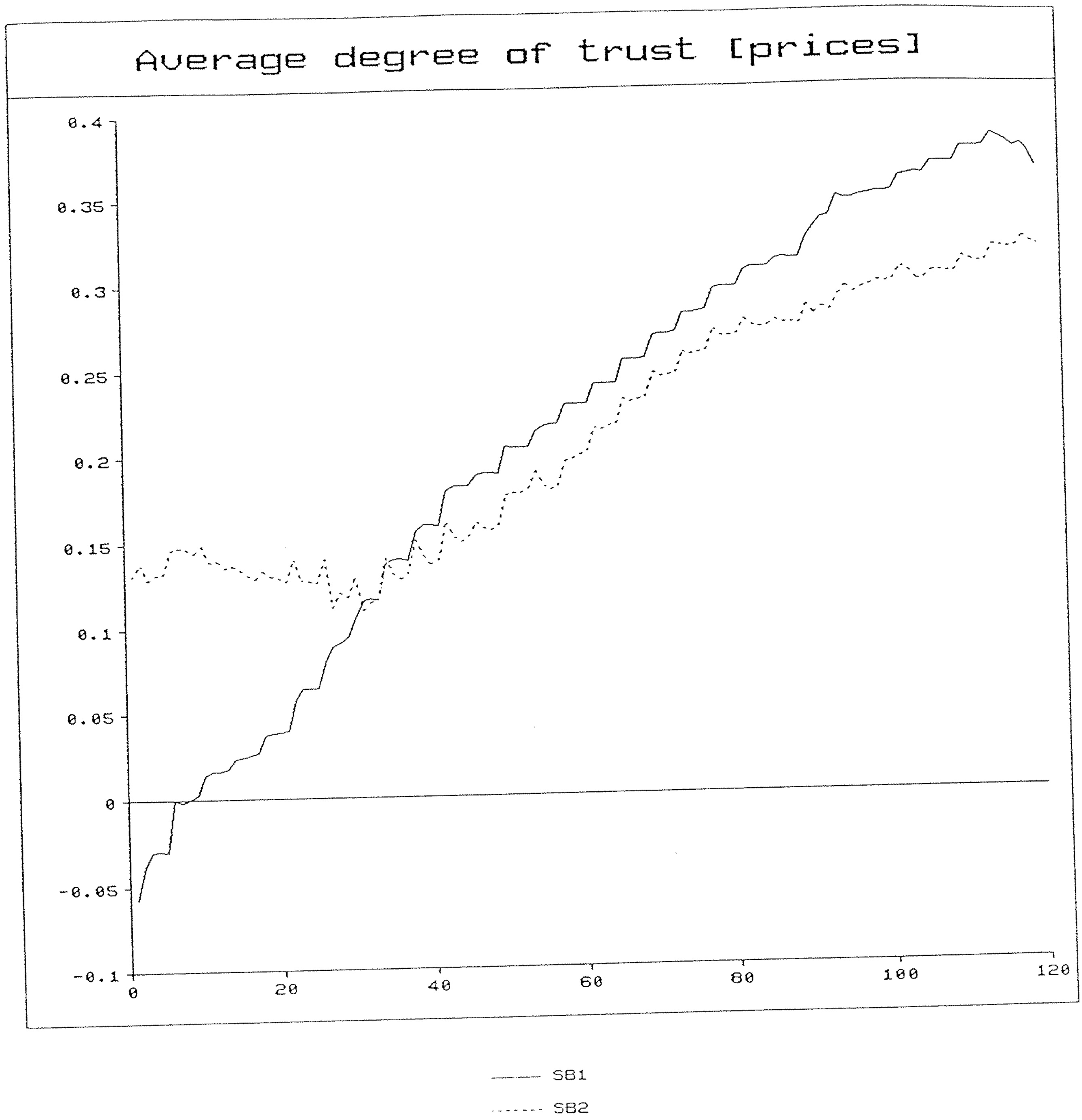


Figure 6.

The origin corresponds to the 50 quarter of simulation runs.


Average degree of trust [prices]
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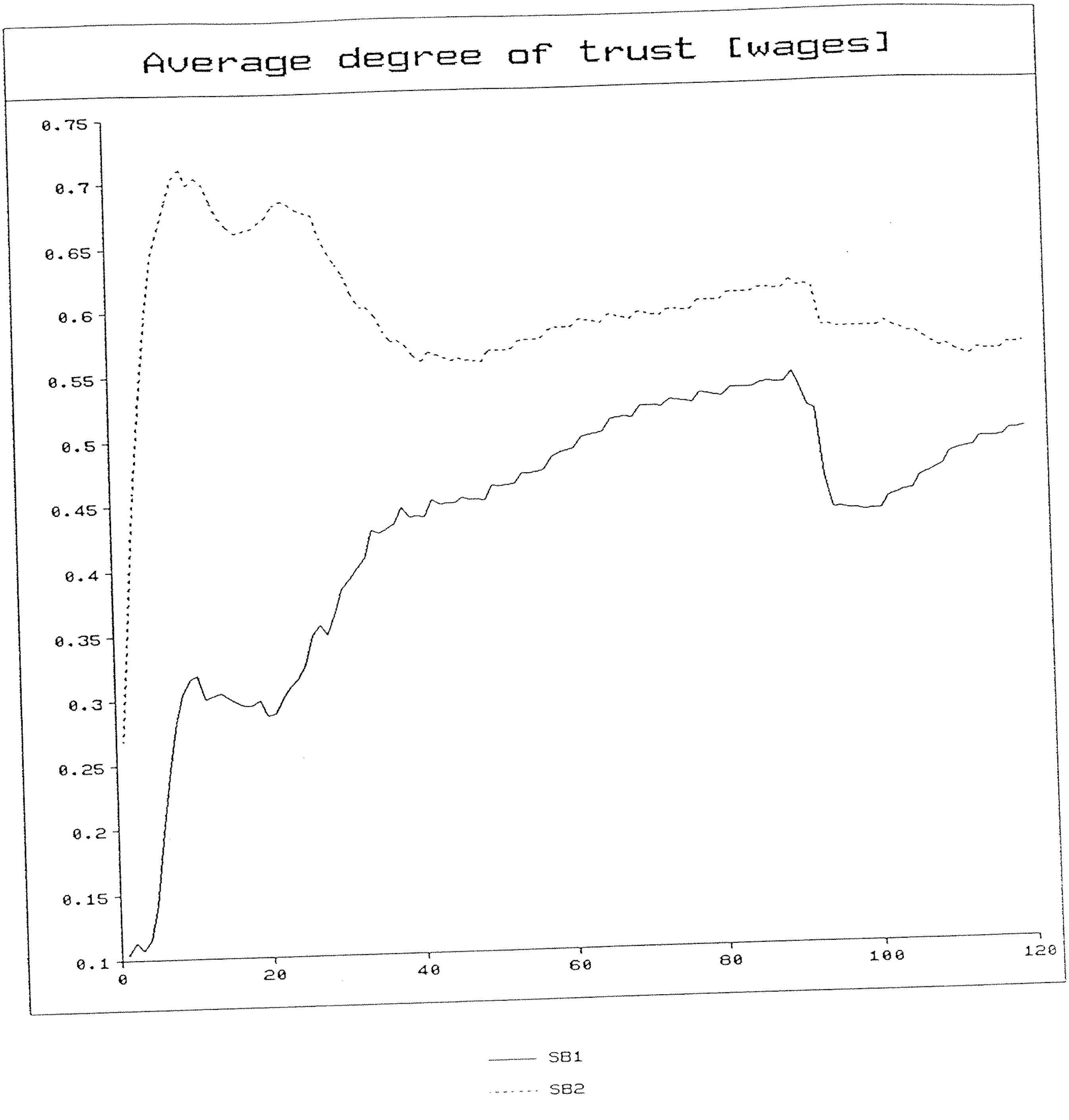
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
0
20
40
60
80
100
120
SB1
SB2

Figure 7.


Average degree of trust [wages]
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0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0
20
40
60
80
100
120
SB1
SB2

Figure 8.

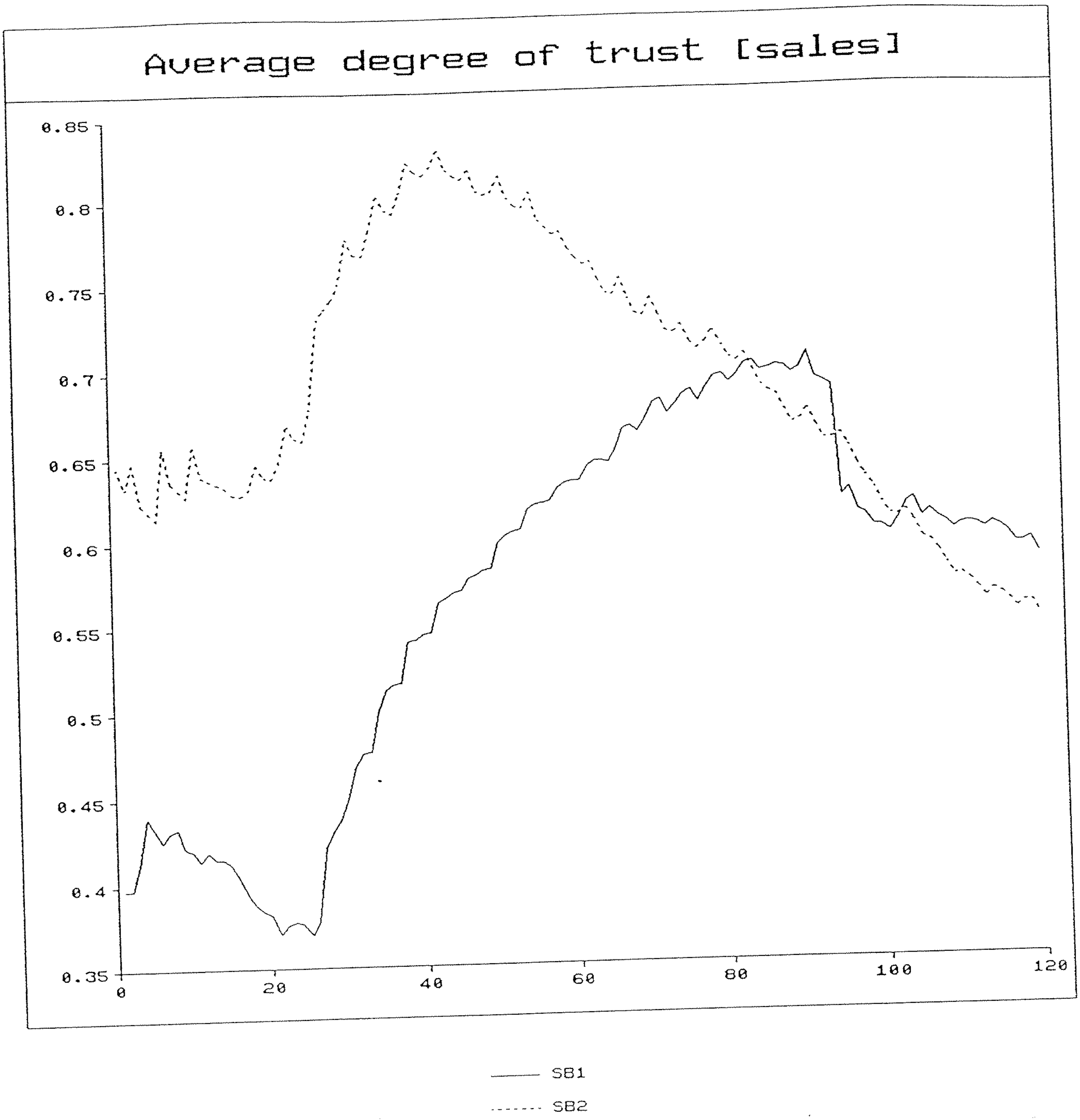
Average degree of trust [sales]
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0
20
40
60
80
100
120
SB1
SB2

Figure 9.

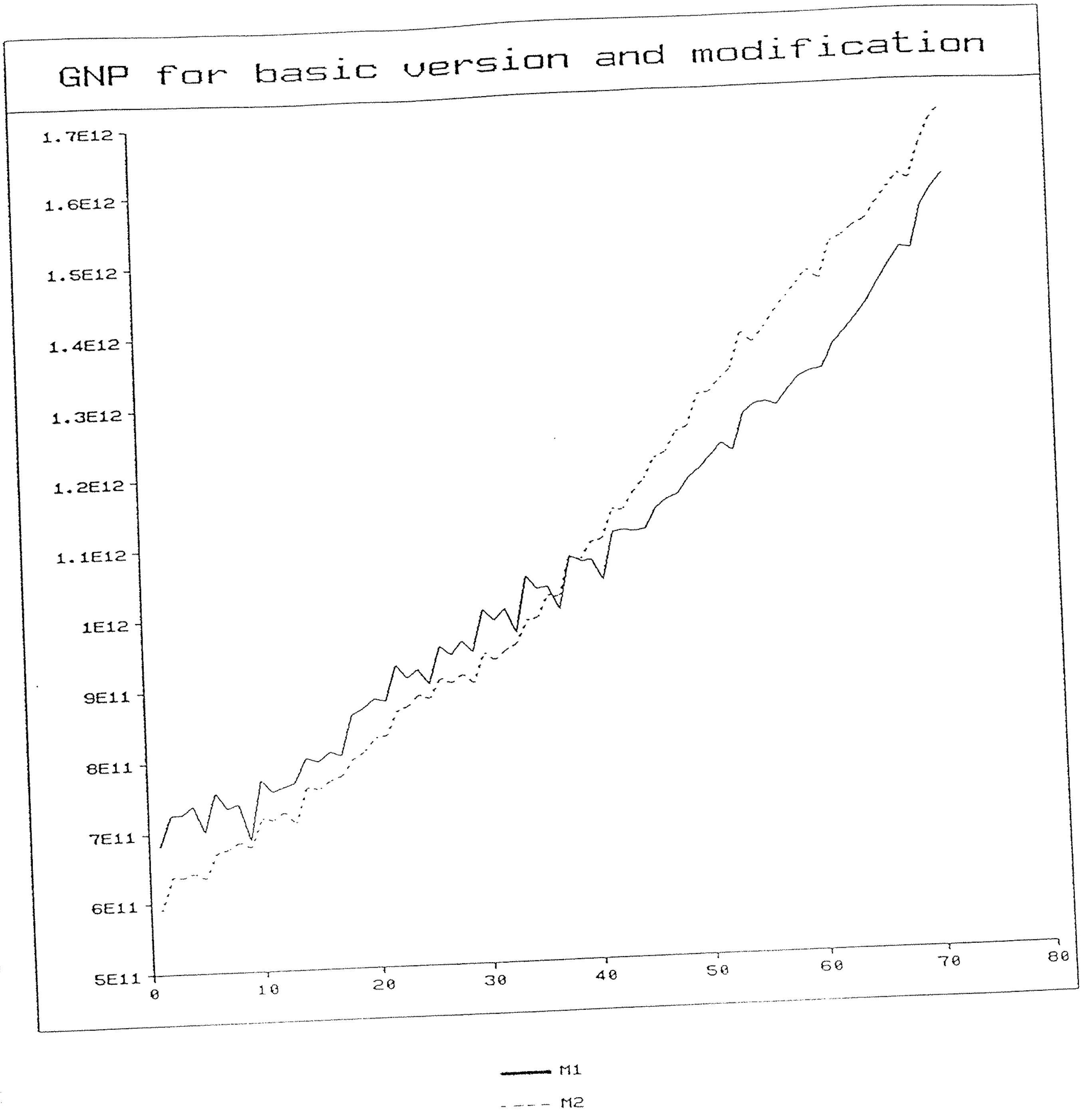

Figure 10. M1 - basic version of MOSES;

M2 - version with both SBs.

The origin corresponds to the 50 quarter of simulation run.

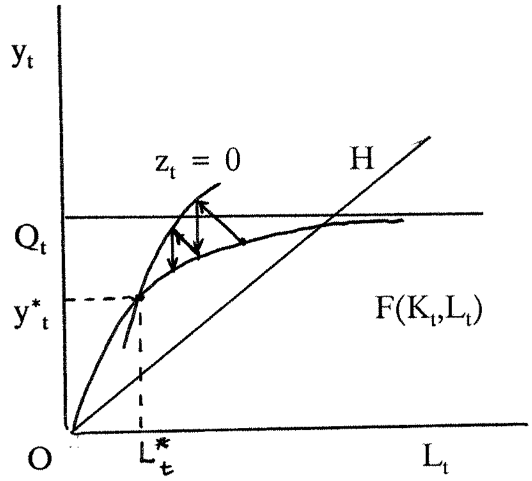

Figure A.1. Quantative adjustment in the SB2 model:

y^*_t, L^*_t - output and employment in equilibrium;

OH - profit-margin target line.