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Abstract: International macroeconomic policy coordination can also be established by a separate supranational coordinator. We will apply hierarchical optimal control theory to the policy-making of the European Community. The coordinator at the higher level (the Council of Ministers) adjusts the actions of the subsystems at the lower level (the EC countries) in order to achieve an overall objective, whereas the subsystems aim at their own individual objectives. Based on the underlying econometric model, we find that the coordinator is capable to mitigate inflationary national policies in trying to attain stage three of European Monetary Union.

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1 Introduction[1]

International macroeconomic policy coordination is high on the agenda for debate among policymakers and academic economists. Events that recently attracked much attention are the summits of the Group of Seven industrial countries and the cooperation between the central banks on exchange-market intervention. Moreover, it is widely acknowledged that the EMU-Treaty agreed in Maastricht (if ratified by the national parliaments) can only be accomplished by intensified coordination and closer cooperation between the EC countries. The main advantage of policy coordination is that, provided policymakers agree on the model of how the world economy behaves, countries will be better off if they coordinate plans, rather than setting their individual policies independently from each other, while taking the policies of the other governments as given (i.e., a Nash-equilibrium).

Economic relations in society can be represented by a complex system of several decision-units (e.g., countries) rather than a single one. We can distinguish between the following two cases. In the first case, the decision-units operate entirely independently from each other. This system is characterized by purely *decentralized control* in which each country follows an isolationistic policy.

In the second case, decision-units aim for coordination in some sense. In this respect, one can establish coordination in two ways. In the first way coordination is a round-table agreement, for example discussing G7 cooperative strategies, to adjust each country's policy. A second way of macroeconomic policy coordination, however, is by means of a supranational coordinator (e.g., the Council of Ministers within the EC). Here, coordination is embodied in a separate policy-maker. We call this type of policy coordination *hierarchical control*. So far, the implications of an (independently) acting coordinator have not been explored. Macroeconomic policy coordination has been concerned almost exclusively with "intergovernmental" coordination (see e.g., Bryant *et al.*, 1988, 1989).

In this paper we will analyze empirically the coordination among economies with a separate

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coordinator, using elements of hierarchical optimal control theory in a linear quadratic framework. Hierarchical control theory has been applied in other disciplines: computer networks, (artificial) neural networks, production processes, enterpreneurial organizations, ecological (including water control) systems (see IMACS 13th World Congress, 1991). In economics hierarchical control theory was introduced by Ito (1988, 1989), Ito & De Zeeuw (1989) and Ito, Plasmans, De Zeeuw, Cervio Pinho and Markink (1991). The present paper builds on these papers. A hierarchical structure can be seen as a pyramid, with the coordinator in the vertex (higher level) and the subsystems in the base of it (lower level). In our hierarchical control framework the coordinator adjusts the actions of the subsystems at the lower level in order to achieve an overall objective, whereas the subsystems aim at their own individual objectives. The subsystems may have common objectives in favour or against the coordinator, or may have competing objectives. According to the underlying econometric model (see Ito *et al.*, 1991), the coordinator's target variables influence the dynamic development of the target variables in the subsystems.

We will use this framework to describe the policy-making process in the European Community. We consider a single policy-maker (i.e., the Council of Ministers together with the European Commission) who tries to coordinate the individual macroeconomic policies of the subsystems (i.e., the EC countries) in order to steer the economy of the system (the European Community) towards a more desirable state. The rationale for applying this hierarchical approach to the EC is threefold.

First, if one tries to model the EC-decision-making process one has to bear in mind that the Community shows some clear federal treats; it has developed its own system of laws and its institutions exercise a clearly defined authority in several areas (Molle, 1991). Applying a hierarchical approach appears thus in accordance with the stratified structure of the EC.

The second reason to introduce hierarchical elements is related to stage three of EMU. There is strong evidence for substantial (net) benefits of one money in Europe (Commission of the European Communities, 1990a)[2]. Although the United Kingdom and Denmark did not make a commitment in the EMU Treaty to move automatically to stage three[3], all EC countries did commit themselves to follow the appropriate policies to achieve convergence in inflation rates, interest rates, budget deficits and other macroeconomic indicators (see EMU Treaty, 1991). As a consequence, countries have to submit convergence programs to the Council of Minsters. In these programs each country will have to show in what way it will meet the criteria for admission to stage three. However, this commitment to converge is not enforceable by law. The only instrument

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[2] See for opposing views Bank for International Settlements (1992) and Martin Feldstein (1992).

[3] As is well known, the Danish people rejected this Treaty by referendum on June 2, 1992.

which the Council has in the run up to stage three is to make (public) recommendations to the member state concerned if its economic policy is not consistent with the convergence tests. As a result, there is no guarantee that the EMU will start with as many qualified countries. Therefore, Europe might suffer a welfare loss the longer the convergence process will take. It is precisely in this respect that a separate coordinator might keep up the pace in this process by pursuing an overall macroeconomic policy consistent with stage three of EMU. In particular we are interested in the question which role the coordinator has to perform in the transition to the final stage of EMU. In this respect, the hierarchical coordination approach can be considered as an alternative to the present intergovernmental macroeconomic coordination strategy to aim for one money, which gives the Community institutions a merely advisory role.

Third, following the distinction of Currie *et al.* (1989), coordination can take an absolute or a relative form [2]. Our approach captures both. We assume there is a separate institution who takes care for macroeconomic performance (e.g. price stability) of the aggregate. This is in striking contrast with the Bretton Woods era when international coordination took the relative form (Currie *et al.*, 1989).

The paper is organized as follows. In the next section, hierarchical elements within the European Community will be discussed. In section 3, the theoretical framework for hierarchical optimal control is presented. We will apply this framework on an estimated macroeconomic model for the European Community in section 4. The results for the optimization procedure will be discussed in section 5. In section 6 two alternative economic policy scenario's are presented. Section 7 concludes. Details of optimal results are given in the appendices.

2 Hierarchy within the EC

The EC is a unique political institution (Collins, 1990). It is therefore helpful to take a brief look inside the current working of the key Community institutions [3].

A major role in this process is played by the **Council of Ministers**, which consists of

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[2] Absolute coordination covers the overall stance of policy in the leading industrial countries and seeks to ensure that, in pursuing separately their own interests, countries do not, in the aggregate adopt excessively tight or loose policies for the world as a whole (Currie *et al.*, 1989 p. 15). Relative coordination, on the other hand, is concerned with the relative positions of countries and therefore focuses on exchange rates and balances of payments.

[3] In doing so we deliberately abstract from the functioning of the European Parliament and the Court of Justice, because these are for our purpose less relevant.

representatives of the governments of member states. According to the treaties, the Council's first concern is *to coordinate the economic policy of the member states.* The Council has furthermore been given the power to take decisions, i.e., it has the *final say* in Community legislation. Finally, the Council is competent to regulate the *Community's relations with other countries* [4].

Since the Single European Act, the so-called **European Council** has also formally been part of the EC institutional machinery. It consists of the heads of governments and the French head of state. Since the 1960s this institution has developed from the "European Summits". The European Council meets twice a year for the purpose of elaborating any strategic decisions.

Within the European Community, another major role is played by the **European Commission.** A very important function of the European Commission is to *initiate policies.* In general, it is the sole institution allowed to propose Community regulations and directives [5]. In this way, the working of the EC depends for a substantial part upon the activity of the Commission, because the Council of Ministers can only act, in a formal sense, on proposals from the Commission. To fulfill this role effectively, the Commission is represented in the meetings of the Council. Although it has no voting rights in Council meetings, the Commission can perform a *mediatory* function between national viewpoints and the general EC interest (Collins, 1990).

A further important function of the Commission is to act as a *guardian of the treaties.* Because it is of vital importance that EC rules are actively applied in each member state, the Commission is responsible for the enforcement of Community law. To this end, it supervises the correct implementation of treaties and decisions [6].

Finally, the Commission is *executing Community policy.* In this respect, it negotiates on behalf of the EC, for example in matters relating to international trade [7].

In sum, the Council coordinates and determines the strategy to be adopted while the Commission takes care of daily operations and supervises the observation of the treaties. Both bodies need each

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[4] Actually, it is mostly the European Commission which acts as a negotiator for the EC, by a mandate given to it by the Council; the final decision is the Council's (Molle, 1991).

[5] For example, it was the Commission who came up in 1985 with the well-known Cockfield White Paper to complete the internal market. This end is to be achieved by doing radically away with all existing barriers among EC member states by the end of 1992.

[6] If, for instance, firms violate repeatedly EC rules, the Commision has the power to *fine* them. Should that remain without result, it is entitled to refer the matter to the Court of Justice.

[7] The Commission also has substantial competences in matters relating to coal and steel, competition and nucleair energy. Further it implements the Community budget including that of the so-called structural Funds. However, a great deal of EC policy (e.g. the day-to-day execution of the Common Agricultural Policy) is not executed by the Commission but by national and regional administrations.

other of course and, in fact, they perform their duties in constant consultation (Molle, 1991).

Behind this description lies of course a very complex decision-making process, where more parties are involved. There is, however, little doubt that, in relation to the formulation and implementation of policy, the two key units are the Council of Ministers and the European Commission. Hence, for simplicity reasons we will treat the Council and the Commission within our hierarchical framework as one entity (henceforth called the Council).

It is important at this stage to note that the Council together with the Commission is not a macroeconomic authority (VanderWal, 1991). It certainly has ambitious goals (Commission of the European Communities, 1990b), but the instruments to reach them lag behind. Because we apply hierarchical control theory to the EC's policy-making process, we assume some macroeconomic instruments are available at the coordinator's level. Altough this is a rather strong assumption, there is little doubt there will be more hierarchical coordination in the near future. According to the EMU Treaty, the second stage of Economic and Monetary Union will be marked by the erection of a new umbrella organization called the European Monetary Institute [8]. The hierarchy becomes even stronger in the full monetary union when member states with e.g. persistent excessive government deficits face Community sanctions (EMU Treaty, 1991, art. 104 §11).

Obviously, modelling a complex decision-making unit as the EC is a cumbersome job and it is almost inevitable to make (sometimes severe) simplifying assumptions. Moreover, it is beyond dispute that economic coordination, as has generally occurred in history, has been a looser and more partial affair than analyzed in the theoretical literature (Currie *et al.*, 1989). In view of these remarks we give an interpretation of EC policy-making within the hierarchical optimal control framework below.

Based on the signals from the individual countries the Council is confronted with a number of target variables as well as desired values for them (we will describe beneath four ways how these desired values might come about). These target variables satisfy, of course, economic relationships determined by the development of these variables in the individual countries. Assuming that the importance of each country can be measured by its gross domestic product (GDP), we collect data that are weighted by the GDP of the individual countries to come to a realistic model for the target variables on EC-level. This model contains as well the instruments as the exogenous deterministic variables of the individual countries. So, based on this model for the target variables

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[8] The EMI shall contribute to the realization of the conditions necessary for the move to the third stage. Its tasks are among others:
- to strenghten the coordination of monetary policy with a view to ensure price stability;
- take over the tasks of the European Monetary Cooperation Fund;
- to hold and manage foreign exchange reserves as an agent for the national central banks (EMU Treaty, 1991, Statute of the EMI).

and the desired values for these, the Council has to come up with attainable, realistic values for these targets. Indirectly, this implies, however, that the Council must also take care of the consequences the choice for certain target variables has on the related values for the instruments (which ultimately have to be set by the individual countries). If they are disproportional the individual countries will never commit themselves to these target variables. For these credibility reasons therefore, it seems reasonable that the Council, in the determination of the values for the targets, also takes the (weighted) desired instrumental variables of the individual countries into account. All these considerations make it plausible that the Council will come up with a set of values for the targets which are chosen such that the sum of weighted discrepancies between targets and instruments from their desired values is minimized.

The next basic assumption in our model is that the optimal values for the coordinator's targets are transmitted to the individual countries, and that they influence the targets of the individual countries.

The final step of our model is then, that we assume that all countries perform an optimizing behaviour. That is, we assume that all countries set their instruments such that weighted differences between actual and desired values for the targets as well as for the instruments are minimized. Formally, this results in the mathematical model of the following section.

3 Theoretical framework

Assumption 3.1 *The dynamics of the economics of the individual countries are assumed to be described by (for $i = 1 \ldots N$) :*

$$y_i(t) = A_i y_i(t-1) + A_{0i} y_0(t-1) + B_i u_i(t) + D_i d_i(t) \tag{1}$$

where $y_i(t) \in \mathbb{R}^{n_i}$ is the state of the i-th subsystem (endogenous variables), $u_i(t) \in \mathbb{R}^{m_i}$ is the control vector (instrumental variables) and the vector $d_i(t) \in \mathbb{R}^{l_i}$ is the purely exogenous data-vector. $y_0(t) \in \mathbb{R}^{n_0}$ is the state of the coordinator-system.

The dynamics of the Council (coordinator in the sequel) are described by :

$$y_0(t) = A_0 y_0(t-1) + B_0 u_0(t) + D_0 d_0(t) \tag{2}$$

where $u_0(t)$ and $d_0(t)$ are the fictive control vector resp. purely exogenous data vector of the coordinator.
For all i, A_i, A_{0i}, B_i and D_i are real matrices of appropriate dimensions. The same goes for A_0, B_0 and D_0.

We assume that in order to achieve a certain objective y_i^*, fixed in advance as an ideal path, each policy maker chooses a control input u_i. He will penalize any deviation of the targets from their desired paths. On the other hand, he likes to keep the control variables within a coherent range of values. This is done by also setting a desired path for the control vector, u_i^*. With this idea in mind, we formulate a welfare loss function for each individual country. A similar welfare loss function is defined for the coordinator. The hierarchical control problem consists now of one control problem for the coordinator, which we call the center problem, and N control problems for the N subsystems, which we call the local problems. Formal our assumptions concerning this welfare loss minimization problems are :

Assumption 3.2 (Center problem)

$$\min_{u_0} J_0 = \min_{u_0} \sum_{t=t_0}^{t_f-1} \left(\|y_0(t) - y_0^*(t)\|^2_{Q_0(t)} + \|u_0(t) - u_0^*(t)\|^2_{R_0(t)} \right) \tag{3}$$

w.r.t. (2).

Assumption 3.3 (Local problem)

$$\min_{u_i} J_i = \min_{u_i} \sum_{t=t_0}^{t_f-1} \left(\|y_i(t) - y_i^*(t)\|^2_{Q_i(t)} + \|u_i(t) - u_i^*(t)\|^2_{R_i(t)} \right) \tag{4}$$

w.r.t. (1).

In these definitions we have introduced the *starting time* t_0, which is a nonnegative integer, and the *end time* t_f. We assume $t_f > t_0$. The weight matrices $Q_i(t)$ and $Q_0(t)$ are assumed to be positive semi-definite. The weight matrices $R_i(t)$ and $R_0(t)$ are assumed to be positive definite. In this way we can garantuee that the resulting optimal control problems are all non-singular.

The solutions of the above stated control problems can be derived using the maximum principle (see for instance de Zeeuw (1984) for details). First we solve the center problem.

Theorem 3.4 *The optimal control for the center problem as defined by 3.2 is given, for* $t = t_0 \ldots t_f - 1$, *by :*

$$\begin{aligned} \hat{u}_0(t) \;=\; & E_0(t+1)^{-1} \left(R_0(t) u_0^*(t) \right. \\ & \left. - \frac{1}{2} B_0^T K_0(t+1) \left[A_0 y_0(t-1) + D_0 d_0(t) \right] - \frac{1}{2} B_0^T g_0(t+1) \right) \end{aligned} \tag{5}$$

where $K_0(t)$ *satisfies, for* $t = t_0 \ldots t_f$, *the following backward Riccati difference equation :*

$$\begin{cases} K_0(t) \;=\; 2Q_0(t-1) + A_0^T K_0(t+1) \left(I - \frac{1}{2} B_0 E_0^{-1}(t+1) B_0^T K_0(t+1) \right) A_0 \\ K_0(t_f) \;=\; 2Q_0(t_f - 1) \end{cases} \tag{6}$$

$E_0(t+1)$ is defined, for $t = t_0 \dots t_f - 1$, by :

$$E_0(t+1) := R_0(t) + \frac{1}{2} B_0^T K_0(t+1) B_0 \tag{7}$$

$g_0(t)$ satisfies, for $t = t_0 \dots t_f$, the following backward difference equation :

$$\begin{cases} g_0(t) &= -2Q_0(t-1)y_0^*(t-1) + A_0^T K_0(t+1)B_0 E_0^{-1}(t+1)R_0(t)u_0^*(t) \\ & \quad + A_0^T K_0(t+1)D_0 d_0(t) - \frac{1}{2}A_0 K_0(t+1)B_0 E_0^{-1}(t+1)B_0^T K_0(t+1)D_0 d_0(t) \\ & \quad + A_0^T g_0(t+1) - \frac{1}{2}A_0 K_0(t+1)B_0 E_0^{-1}(t+1)B_0^T g_0(t+1) \\ g_0(t_f) &= -2Q_0(t_f-1)y_0^*(t_f-1) \end{cases} \tag{8}$$

Next, we solve the N local problems :

Theorem 3.5 *The optimal control for the local problem as defined by 3.3 is given, for $t = t_0 \dots t_f$, by :*

$$\begin{aligned} \hat{u}_i(t) &= E_i(t+1)^{-1} \Big(R_i(t)u_i^*(t) \\ & \quad - \frac{1}{2}B_i^T K_i(t+1)\left[A_i y_i(t-1) + A_{0i}\hat{y}_0(t-1) + D_i d_i(t)\right] - \frac{1}{2}B_i^T g_i(t+1) \Big) \end{aligned} \tag{9}$$

where $K_i(t)$ satisfies, for $t = t_i \dots t_f - 1$, the following backward Riccati difference equation :

$$\begin{cases} K_i(t) &= 2Q_i(t-1) + A_i^T K_i(t+1)\left(I - \frac{1}{2}B_i E_i^{-1}(t+1)B_i^T K_i(t+1)\right)A_i \\ K_i(t_f) &= 2Q_i(t_f-1) \end{cases} \tag{10}$$

$E_i(t+1)$ is defined, for $t = t_i \dots t_f - 1$, by :

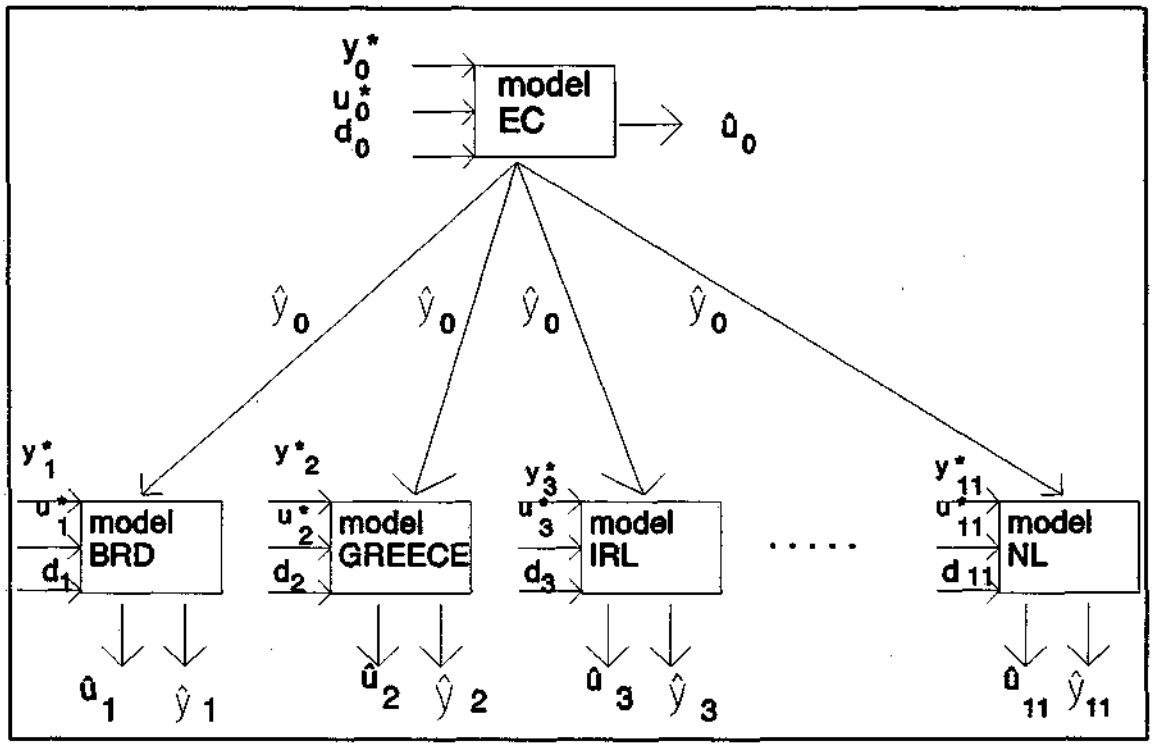
$$E_i(t+1) := R_i(t) + \frac{1}{2} B_i^T K_i(t+1) B_i \tag{11}$$

$g_i(t)$ satisfies, for $t = t_0 \dots t_f$, the following backward difference equation :

$$\begin{cases} g_i(t) &= -2Q_i(t-1)y_i^*(t-1) + A_i^T K_i(t+1)B_i E_i^{-1}(t+1)R_i(t)u_i^*(t) \\ & \quad + A_i^T K_i(t+1)\left[D_i d_i(t) + A_{0i}\hat{y}_0(t-1)\right] \\ & \quad - \frac{1}{2}A_i K_i(t+1)B_i E_i^{-1}(t+1)B_i^T K_i(t+1)\left[D_i d_i(t) + A_{0i}\hat{y}_0(t-1)\right] \\ & \quad + A_i^T g_i(t+1) - \frac{1}{2}A_i K_i(t+1)B_i E_i^{-1}(t+1)B_i^T g_i(t+1) \\ g_i(t_f) &= -2Q_i(t_f-1)y_i^*(t_f-1) \end{cases} \tag{12}$$

Below, we will present in Figure 1 a summary of our hierarchical optimal control model. If the desired paths of the coordinator (y_0^*, u_0^*) and the d_0 vector are given, we are able to solve the center problem for the simulation period. This gives optimal values for the coordinator's target and control vectors $\hat{y}_0$ and $\hat{u}_0$ respectively. Then the coordinator transmits $\hat{y}_0$ to each subsystem, which, from the latter's point of view, is exogenous. Together with the desired paths of every subsystem, y_i^* and u_i^* and the purely exogenous vector d_i, all the N local problems can be solved for the planning period, which gives optimal values for each country's target and control vectors $\hat{y}_i$ and $\hat{u}_i$ respectively.

Figure 1 Stylized hierarchical optimal control model



4 Application on an econometric model for the EC

4.1 The model

To analyse the optimal coordination in the European Community, Ito *et al.* (1991) [9] built an annual econometric model which allows for the application of the theory being exposed above. The model is based on the COMET-V model (see Duerinck & d'Alcantara, 1988) for the Community. According to the previous sections we distinguish two levels of policy-making.

The first level is the policy-making by the coordinator, the Council, which is an aggregate of the EC countries. The second level comprises the policy-making process by the individual EC countries. All EC countries are modelled with the exception of Luxembourg (left out because its GDP represents less than 0.2% of the EC's GDP). The model consists of 8 linear behaviourial equations for each country and for the coordinator. A definitional equation for the current account of the balance of payments is also included. The specification of the vector of endogenous variables

[9] The definitions and data-sources of the variables used in the model are given in Ito *et al.* (1991), Appendix A.

is given in Table 1.

Table 1 Endogenous (Target) Variables

CPO	household consumption in constant '80 prices
IPO	investment (other than residential or governmental) in constant '80 prices
XTO	total exports in constant '80 prices
MTO	total imports in constant '80 prices
PY	GDP's deflator ('80 = 100)
UR	unemployment rate
FMD	money stock in current prices
PXT	price index of total exports ('80 = 100)
TB	current account balance

A list of the instrumental variables used is given in Table 2.

Table 2 Instrumental (Control) Variables

SIR	short term interest rate
LIR	long term interest rate
EXR	nominal exchange rate vis à vis the US dollar
WGU	compensation of employees of the general government in current prices
NG	total employment of the general government
ITR	indirect tax rate
SSHR	rate of social security contributions of households
DTCR	direct tax rate on companies' profits
DTHR	direct tax rate on households' income
SUB	subsidies in current prices

The purely exogenous data, i.e. the d_0 (t) and d_i (t) vectors in equation (1) and equation (2) occurring in this multicountry model are: disposable income, GDP in constant 1980 prices, gross operating surplus of companies, the price index of the competitors' weighted tradable goods, the price index of imports and the total wage compensation of employees.

Over the sample period, the values for the EC are obtained as an aggregation of the values of each country expressed in dollars, whereas the countries' variables are measured in their national currency. The EC's values for the price indices, unemployment rates, interest rates, taxes and social security rates are calculated as a weighted sum of the values of each country. The population variables are, obviously, a simple sum of the variables.

We now turn briefly to the model equations. On the EC level, each endogenous target variable is explained by (lagged) endogenous variables (y_0), instrumental variables (u_0) and purely exogenous ones (d_0). *Mutatis mutandis* this applies also for the individual countries. However, in the individual country equations the lagged coordinator's target values are introduced. In section 3 eq. (1) this is represented by the y_0 (t-1) vector, where the A_{oi} matrix comprises the quantitative influence of these coordinator's (lagged) targets on each country's target variable. Because the variables of the coordinator are (weighted) sums of the individual country's variables, $A_{oi}\,y_0$ (t-1) represents also the economic linkages between the countries, albeit in an indirect way.

To facilitate the comparison between the country models, we imposed a similar structure on them. First, this is reflected by explaining the same targets for each country by the same instruments and endogenous variables. For example, for each country the dollar exchange rate is considered an instrument that can be used to control the volume of exports. The same can be said of the interest rate being a policy instrument for the volumes of consumption and investment and for the money supply.

Second, the similarity in the model structure is also reflected in the explicit coordinator's influence on the country's targets equations [10]. We measured that influence by estimating the contribution of the coordinator's values for the current account balance (TB), real GDP, the GDP deflator (PY) and the unemployment rate (UR) to the appropriate country target variables. So we

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[10] For example, the export price equation of Belgium is mainly explained by:

$$PXT^{BEL} = PXT^{BEL}(EXR_{BF/\$}\ PY_{-1}^{BEL}, PXT_{-1}^{BEL}, GDP_{-1}^{BEL}; GDP^{EC}, PY_{-1}^{EC}) .$$

So if the Council would like to fight inflation, the rise in the price index PY^{EC} should decrease and would affect after one period the Belgian export prices. To keep with the same country, another example is the Belgian investment equation:

$$IPO^{BEL} = IPO^{BEL}(GDP^{BEL}, IPO_{-1}^{BEL}, PY_{-1}^{BEL}, TB_{-1}^{BEL}, UR_{-1}^{BEL}; GDP^{EC}, UR^{EC}) .$$

The volume of Belgian investments is explained not only by its own variables, but also by the development of the GDP and the unemployment on the EC level, the latter two representing final demand opportunities within the EC area.

can split each country equation in two parts: the first part consists of country variables while in the second part the coordinator's variables are added.

Using macro-economic data over the sample period 1960-1986 for each country eq. (1)-(2) of section 3 have been estimated and tested (Ito *et al.*, 1991).

Before we can compute the hierarchical control solutions, we need desired paths for the target (endogenous) variables and the control variables. For the center problem we will discuss four ways how the desired paths for the target and control variables might come about. In what is called a *Top-Down policy*, we assume that the coordinator determines his own desired paths. Another possibility is a *Bottom-Up policy*: the desired paths for the coordinator are calculated as the (weighted) sums of the desired paths of the subsystems. Further, in Ito *et al.* (1991) also a *constrained Top-Down* and a *constrained Bottom-Up policy* are defined. In the case of a constrained Top-Down policy the coordinator determines his own desired paths for the target variables but the desired paths for the control variables are calculated as in the Bottom-Up case. The constrained Bottom-Up policy works just the other way round: the coordinator determines the desired path for the control variables, and the desired paths for the targets are calculated as in the Bottom-Up case. More informative structures can be considered within the constrained policies (i.e., divide the control variables into groups, depending on the various possibilities the coordinator has to control these variables). Nevertheless, we have computed (only) the four types of information exchange explained above.

The following scheme summarizes these types of information exchange:

	$u_o^* = \Sigma \alpha_i u_i^*$	u_o^*
$y_o^* = \Sigma \beta_i y_i^*$	Bottom-Up	Constrained Bottom-Up
y_o^*	Constrained Top-Down	Top-Down

where y_o^* and u_o^* are the coordinator's desired target and desired control vectors respectively, while $y_o^* = \Sigma \beta_i y_i^*$ and $u_o^* = \Sigma \alpha_i u_i^*$ are the same vectors but considered as a (weighted) sum of the subsystems' desired target and desired control vectors respectively.

4.2 On the road to EMU

In this section we will motivate the way we specified the desired paths for both the target and

instrumental variables. Our reference point will be stage three of the EMU Treaty [11]. It is well known that this stage includes the irrevocable fixing of exchange rates, leading to the introduction of a single currency. Further, a European central bank will be established which implies the conduct of a single monetary policy and exchange rate policy the primary objective of both shall be to maintain price stability (EMU Treaty, 1991).

The desired paths are chosen in such a way that nearly all countries meet the monetary [12] convergence tests required to enter full monetary union. This implies that all countries are targeting converging (i.e., lowering!) inflation rates resulting in an inflation rate in 1995 (i.e., the reference year of examination) which does not exceed that of at most the three best price performing member states by more than 1½ percentage points (EMU Treaty, 1991, Protocol on the convergence criteria). It is assumed that Germany strives for an inflation rate of 2½% during 1987-1990 (which is close to the actual rate) and for 2% during 1991-1995, which reflects the desire by the Bundesbank (Schlesinger, 1992). Only for Greece and Portugal it is supposed that these countries do not wish to lower their inflation rates that far, because of their high initial inflation. Nevertheless, we assumed these two countries are striving for convergence too. The desired paths for the interest rates have been made consistent with the desired inflation for each country, according to the Fisher-relation. Here, also, the convergence criterion of the Treaty has been taken account of [13]. As far as the growth of the money supply is concerned it is assumed that the desired money growth rates are gradually lowered, consistent with the lowering of the inflation rates and taking into account national differences in the growth of productive capacity.

The desired exchange rate of the US dollar has been set in such a way that from 1991 on exchange rates between the countries participating in the Exchange Rate Mechanism (ERM) will be fixed at central parity. Intra-European exchange rate stability can of course coincide with different movements of the dollar. In this paper we suppose a constant dollar exchange rate vis à vis the EMS-bloc. For Greece and Portugal, which do not participate in the ERM [14], we assume that their exchange rates follow Purchasing Power Parity, as has roughly been the case over the last

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[11] Here it is not the right place to discuss the new political situation which emerged after the Danish no against the Maastricht Treaty. Nevertheless, one can be quite sure that Denmark does not have great difficulties with the application of the convergence criteria we are analyzing in this paper, because it already meets them.

[12] In future research the convergence criteria relating to the fiscal variables (i.e. the government deficit and the government debt) will be taken account of.

[13] This criterion says that in 1995 the average long-term interest rate of a member state should not exceed that of the three best price-performing member states by more than 2% points (EMU Treaty, 1991, Protocol on the convergence criteria).

[14] This analysis was done before Portugal joined the ERM on April 6, 1992.

ten years.

We now turn to the variables of the coordinator. The Council, it is argued, is very keen to establish the full monetary union. Therefore, we assume that the EC desires the same low inflation and interest rates path as Germany. The desired money supply growth rate of the EC has been set at 6%, reflecting desired inflation and assuming approximately a 4% growth in EC's productive capacity.

Overseeing the coordinator's wishes, one can conclude a desire to perform as a second anchor, after Germany, to ensure the road to EMU is a sound one. Although this is not a guarantee for price predictability in the sense of Friedman (1986), the coordinator might act as an extra safety valve. This opens up the possibility that, might Germany take compromises on inflation because of internal and external political pressures, there is still a second, coordinating, monetary authority, making it difficult to raise the European inflation-anchor.

As far as the other variables (e.g. unemployment) are concerned, we assume that their desired paths follow realistic trends, consistent with recent realizations and projections given by the OECD (OECD, Economic Outlook, 1991). Further, the desired values for as well indirect and direct tax rates for households and companies as the social security contributions of households are kept constant. Finally, the purely exogenous variables are set according to realizations and projections of the OECD. In sum, for the desired targets we tried to assume realistic and credible values, while at the same time retaining the neccesary monetary policies to meet the convergence tests. In Appendix A the most important desired paths of targets and instruments related to 1991-1995 are shown.

The final step before computing the optimal solutions, is to attach weights to the target and control variables, according to the priority given by the policy-makers. Because of the importance to meet the convergence tests, we put a double penalty on deviations from the desired paths for inflation, exchange rates, interest rates and money supply, or formally:

$Q_j^*(t) = 1/y_j^*(t)^2$ with j = CPO, IPO, XTO, MTO, UR, PXT and
$Q_j^*(t) = 2/y_j^*(t)^2$ with j = PY, FMD;
$R_j^*(t) = 1/u_j^*(t)^2$ with j = WGU, NG, ITR, SSHR, DTCR, DTHR, SUB and
$R_j^*(t) = 2/u_j^*(t)^2$ with j = SIR, LIR, EXR.

5 Results

In this section we present the results for the optimal paths of the target and instrumental variables for the simulation period 1987-1995, given the estimated model, the desired paths and the projections of the purely exogenous variables.

In Table 3 Theil inequality coefficients for the target variables are shown. We restrict ourselves to Top-Down and Bottom-Up solutions only, because the Constrained Top-Down and the Constrained Bottom-Up policies show optimal values similar to the Top-Down and the Bottom-Up solutions respectively. Theil-coefficients [15] measure the relative distance between the hierarchical optimal control solutions and the corresponding desired values.

In general, Top-Down solutions appear substantially more efficient than Bottom-Up solutions. This clearly applies for France, Italy, The Netherlands, Belgium, the United Kingdom, Denmark and Spain. The optimal values for their target variables track their desired paths quite well. The Theil coefficients are almost equal to or below 0.4, which is considered as a critical value. Only for Italy (CPO, IPO), Greece (FMD, PXT) and Spain (IPO, MTO, PY, FMD, PXT) the Theil coefficients are too high.

Looking at the targets, in particular the variables for IPO and FMD show a high inequality value, especially in the Bottom-Up case. The lower performance of the optimal investment paths (IPO) may be related to the relatively low explanatory power of investment equations, which showed also up in the estimates. For FMD, even Top-Down inequality coefficients are rather high for Denmark, Ireland, Greece and Spain. For these last three countries, this is due to the imposed desired money growth rates of the EC-coordinator, which appear too restrictive for these countries. In this model, the money supply seems to be the most difficult variable to target. This appears to be quite general in practice.

As far as inflation is concerned, it can be seen that all countries' optimal inflation paths are very close to their desired paths. This is remarkable because the coordinator's inflation targets in the Top-Down strategy has been rather restrictive (i.e., an annual inflation rate of 2% in 1991-1995). This implies that converging and lower inflation rates, as is required for entering the third stage of EMU, is attainable for a number of EC countries, provided the coordinator follows a tight (=Top-Down) policy.

Optimal unemployment paths are close to the desired ones for nearly each country. Here, the low Theil coefficients imply that a tight monetary policy will not harm unemployment. On the contrary, the slightly declining unemployment rates we assumed to be the ideal policies until 1995 appear to be attainable. We return to this issue in the next section.

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[15] Theil-coefficients are defined as $$T_{\Delta_i} = \frac{\sqrt{\sum_t (a_{it}^* - a_{it})^2}}{\sqrt{\sum_t (a_{it}^*)^2}}$$

where a_{it} = optimal target/control variable
a^*_{it} = desired target/control variable
i = countries and coordinator
t = 1987-1995

Table 3 **Theil inequality coefficients target variables**

	DB	FR	IT	NL	BE	UK	IR	DK	HE	PO	ES	EC
CPO	0.05	0.07	0.53	0.09	0.03	0.16	0.08	0.06	0.06	0.15	0.21	0.06
	0.05	0.24	0.84	0.40	0.05	0.05	0.09	0.11	0.03	0.10	0.31	0.53
IPO	0.32	0.05	0.52	0.19	0.21	0.12	0.44	0.29	0.09	0.18	0.55	0.19
	0.29	0.11	0.59	0.43	0.76	0.07	0.24	2.36	0.25	0.14	2.27	0.69
XTO	0.09	0.20	0.26	0.06	0.07	0.13	0.06	0.07	0.35	0.67	0.25	0.08
	0.06	0.17	0.08	0.21	0.16	0.29	0.11	0.14	0.43	0.48	0.16	0.48
MTO	0.25	0.16	0.30	0.04	0.15	0.15	0.38	0.12	0.03	0.12	1.34	0.09
	0.17	0.08	0.25	0.03	0.10	0.07	0.36	0.09	0.01	0.09	1.74	0.59
PY	0.15	0.06	0.01	0.04	0.05	0.04	0.36	0.02	0.30	0.20	0.95	0.15
	0.08	0.17	0.13	0.46	0.17	0.12	0.21	0.05	0.26	0.16	1.61	0.03
UR	0.00	0.09	0.04	0.01	0.00	0.00	0.20	0.00	0.08	0.10	0.04	0.00
	0.00	0.04	0.03	0.01	0.01	0.01	0.25	0.02	0.04	0.08	0.04	0.00
FMD	0.15	0.08	0.30	0.15	0.28	0.20	0.47	0.55	1.13	0.38	0.73	0.20
	0.12	0.04	0.65	0.49	0.44	1.56	0.16	0.85	1.48	0.49	0.48	0.50
PXT	0.19	0.05	0.09	0.14	0.14	0.37	0.37	0.05	1.39	0.09	0.86	0.08
	0.10	0.12	0.23	0.25	0.36	0.56	0.61	0.17	1.88	0.14	1.35	0.07
TB	0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.14	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

Table 4 **Theil inequality coefficients control variables**

	DB	FR	IT	NL	BE	UK	IR	DK	HE	PO	ES	EC
SIR	0.22	0.02	0.01						0.14	0.36		
	1.13	0.03	0.08						0.14	0.20		
LIR				0.08	0.03	0.05	0.21	0.12			0.23	0.28
				0.60	0.19	0.06	0.15	0.26			0.28	0.94
EXR	0.07	0.06	0.05	0.07	0.11	0.41	0.07	0.21	0.37	0.39	0.31	
	0.20	0.09	0.45	0.41	0.83	1.05	0.15	0.23	0.16	0.27	0.63	
WGU	0.18	0.73	0.34	0.25	0.05	0.14	3.12	0.13	3.94	1.23	0.08	0.14
	0.30	0.14	0.61	0.31	0.03	0.50	3.17	0.10	1.92	0.23	0.11	0.04
NG	0.01	0.17			0.00		0.01	0.00	0.04	0.15	0.01	0.04
	0.01	0.05			0.00		0.01	0.00	0.03	0.07	0.01	0.01
ITR	0.30	0.31		0.00	0.01	0.03	0.22	0.02	0.00	0.02	0.10	0.53
	1.16	0.59		0.01	0.03	0.02	0.16	0.02	0.00	0.02	0.16	1.01
SSHR					0.00		0.00		0.00	0.00		
					0.00		0.00		0.00	0.00		
DTCR	0.00		0.01	0.02			0.00	0.04	0.00			0.00
	0.00		0.02	0.04			0.00	0.13	0.01			0.01
DTHR						0.00	0.00					
						0.00	0.00					
SUB	0.02			0.03	0.00		0.22	0.02			0.02	
	0.02			0.09	0.01		0.23	0.07			0.05	

1st: Top-Down (mon/mon)
2nd: Bottom-Up

Looking at the Theil inequality coefficients for the control variables in Table 4, we observe in general the same pattern as in Table 3. Top-Down policies produce significantly more efficient solutions than Bottom-Up policies. In addition, the countries' Theil's coefficients are small. Only for the instrument WGU there are somewhat higher Theil values.

We observe that the optimal paths for the interest rates and the exchange rates track their respective desired paths quite well. So a lot of countries show to be capable to keep to a rather restrictive path concerning those variables. This is of course an important conclusion for the transition to the third stage of EMU. In fact, looking at the Top-Down solution in Figure 2 for a number of European exchange rates vis à vis the D-mark, the guilder, the Belgian and French franc, the lire and the Irish pound are keeping pretty well together. Moreover, for the guilder the ERM-criterion (i.e., a maximum fluctuation margin against the D-mark of 2.25% on both sides of the central rate, which has been set in this figure at 100), is met. This is consistent with the *de facto* monetary union that exists between Germany and The Netherlands (Commission of the European Communities, 1990a). Most other currencies, i.e., the French franc, the lire and the Belgian franc show slightly depreciating tendencies vis à vis the D-mark, which is in accordance with their cumulated inflation differentials with Germany since 1991. The British pound shows a clear tendency to depreciate and starts, moreover, on a too high level. One should bear in mind, however, that the model has been estimated before the pound joined the ERM. In general, the results presented in Figure 2 are encouraging because the exchange rate was not considered as a target variable. If that would be the case, it could be steered within a narrow range, for instance by an interest rate policy or by exchange market interventions.

In Table 5 we present results with respect to the square root of the sum of performance costs. Because we are interested in an overall measure per country, we analyzed the total costs of deviating from the desired target and control variables over the simulation period. This index measures the welfare loss which each country has to incur by applying a policy that differs from the ideal (desired) one. It is defined as:

$$SRSPC_i = \sqrt{\sum_t \|\hat{y}_i(t) - y_i^*(t)\|^2_{Q_i(t)} + \|\hat{u}_i(t) - u_i^*(t)\|^2_{R_i(t)}}$$

Note that these indices cannot be compared with over countries, but only for different policies per country and for the EC coordinator. With the exception of Ireland, Greece and Portugal, it turns out that in all countries the welfare loss is the lowest if the coordinator follows a (constrained) Top-Down policy. This means that most countries are incurring the smallest costs if the EC as a

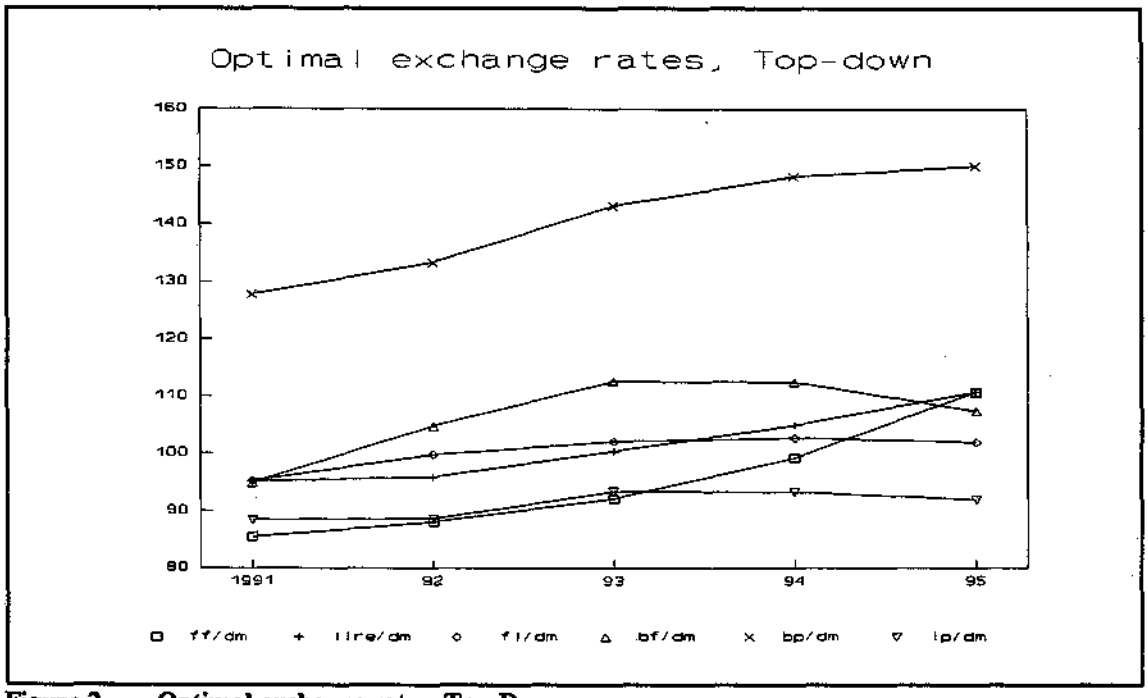

Figure 2 Optimal exchange rates, Top-Down

macroeconomic authority keeps to the tight monetary policy consistent with stage three of EMU. Equivalently, we can say that the costs of deviating from the ideal paths are greater for countries with a historical record of relatively low inflation rates [16] in the case the coordinator determines his desired paths as a weighted average of the subsystems' desired paths (i.e., a Bottom-Up or a loose monetary policy).

Further, it is interesting to note that for Ireland, Greece and Portugal a Bottom-Up approach is preferred. This implies that these countries are better off if the EC takes also into account less tight monetary policies. This outcome is closely related to the economically less advanced state of their economies, making it more difficult for them to track the more demanding path of the coordinator. We observe that Germany and The Netherlands have a strong preference for a Top-Down policy. This is due to the the fact that these countries' desired paths, to a great extent, coincide with the desired paths of the coordinator. For example, in monetary matters, as we have seen, both countries benefit from a low-inflation policy of the coordinator, and these results are obvious from Table 5.

For the EC as a whole a constrained Bottum-Up policy is preferred. So the Community is incurring the smallest welfare loss if the individual countries transmit their desired targets to the coordinator, while the latter determines his own genuine desired evolution for the control variables. As a consequence, one could tentatively conclude that it is more efficient to let the Council decide

[16] In particular Germany, France, the Netherlands, Belgium and Denmark.

about the best value of his own macroeconomic instruments (like the interest rate - the ECU rate - and some Community tax rates), while the countries should be invited to communicate their desired target paths.

Table 5 Square root of the sum of performance costs

Countries	Top-Down	Bottom-Up	Constrained Top-Down	Constrained Bottom-Up
Germany	1.97	3.74	1.96	3.74
France	1.04	1.82	1.04	1.81
Italy	0.35	0.77	0.35	0.77
Netherlands	0.86	5.92	0.87	5.94
Belgium	0.41	1.50	0.42	1.49
United Kingdom	0.46	0.83	0.46	0.83
Ireland	1.86	1.40	1.85	1.40
Denmark	0.75	1.34	0.75	1.33
Greece	1.24	1.11	1.23	1.11
Portugal	0.97	0.68	0.97	0.68
Spain	3.00	4.11	2.98	4.12
EC	2.22	2.07	2.79	1.17

By way of example, we would like to analyze some results in more detail, since they may be of particular interest. The graphics of these examples can be found in Appendix B.

First, Figure B.1 shows the great difference between the optimal path under a Top-Down and under a Bottom-Up policy for the Dutch inflation rate. Apparently, the Dutch economy benefits most if the EC follows a low-inflation policy (i.e.,Top-Down) rather than to accommodate the EC's inflation average, which takes into account the higher inflation rates in Greece, Portugal, Spain, the UK and Italy.

Second, Figure B.2 demonstrates the great inefficiency Germany encounters if the EC is following a Bottom-Up interest rate policy, which reckons also with the higher interest rates in other EC countries. For the sake of an independent German monetary policy, it is in the interest of the Bundesbank to induce the EC to follow a restrictive monetary policy. However, if the EC would adopt a relatively accommodative monetary stance (i.e., Bottom-Up), it is optimal for Germany to raise its interest rates to a great extent in 1989-1990, and lower them afterwards, to reach exactly the desired 4% short-term interest rate in 1995.

For Greece Figure B.3 shows that the way desired paths for the Council are specified, has a

negligible influence on the Greek optimal unemployment path. This is so because the Greek unemployment rate is of about the EC average. Only in 1995 there is some divergence of optimal paths.

Finally, in matters related to the indirect tax rate, Germany is far better off with a Top-Down policy by the coordinator (Figure B.4). According to our definitions, the desired (constant) indirect taxes by the EC are of about the same rate as in Germany (28% resp. 25%) over the simulation period. However, most other neighbour countries prefer higher rates (e.g., Holland, France, the UK, Denmark). As a consequence, a Bottom-Up policy by the EC, which also takes into account the higher indirect tax rates, does not fit to the German situation because of its inefficiency.

6 A Keynesian scenario for Europe

In the previous section we presented results for the EC countries assuming almost ideal paths viewed from the perspective of the supporters of EMU. It was shown that most countries would benefit if the Council would pursue a tight monetary policy (instead of a loose policy). This conclusion is subject to the condition that the individual countries are following the "right" EMU policies too. However, there is insufficient reason why all countries should comply with the convergence tests at the same time. Each country has to decide if stage three is in its own interest. In this section, therefore, we are presenting another scenario, i.e. other desired paths for these individual countries. The main reason is to show what will happen in case the appropriate EMU policies are not pursued. By then, we will also have an idea about the sensitivity of the model outcomes for different desired paths. In addition, we will be able to show what macroeconomic role the coordinator has to play if the individual countries do not care much for EMU, while the coordinator does. As a consequence, there will be conflict between the Council's preferences and the countries'. It would be interesting to see what intervening potential, if any, the coordinator has to direct the countries to stage three. In addition, we will also analyze the situation when not only the countries, but also the coordinator pursues a Keynesian policy. So we will investigate two alternative scenario's.

For the individual countries we assume they now prefer policies which are more Keynesian in nature, i.e. they aim for higher inflation and for lower unemployment rates. This translates into higher interest rates and requires of course more expansive money growth rates. We also assume the governments like to employ more civil servants (increase in NG). The total wage compensation of these employees (WGU), which is also lifted by higher inflation, has to be increased accordingly.

Because in the first scenario the Council still aims for the EMU within the given time schedule, we assume the same desired values for the coordinator as in section 4.2 (Appendix C shows these Keynesian desired paths).

6.1 Results

In this section we will emphasize the comparison of the EMU-scenario in section 4-5 with the two alternative scenario's. For ease of exposition, in the following we will denote the EMU-scenario as mon/mon, the first alternative scenario as mon/keyn and the second alternative as keyn/keyn [17]. The Theil inequality coefficients of these two scenario's are summarized in Tables 6 and 7. The first row for each variable represents the mon/keyn situation and the second row the keyn/keyn one. Let us first look at the situation where the Council follows EMU policies, while the countries pursue Keynesian policies (i.e. mon/keyn or the first alternative scenario). In this situation the Theil coefficients are relatively small. So for most countries and for most targets and instruments, the optimal paths are close to the desired paths. Exceptions are some coefficients in the investment and money stock equations, probably due to specification errors. In the second alternative scenario, the EC-coordinator follows a Keynesian policy too. This is. however, not implemented as in a Top-Down transmission structure, but in a Bottom-up fashion [18] (i.e. the desired paths of the Council are constructed taking the desired Keynesian policies of the EC countries as a weighted average). As can be seen, the Theil coefficients now are significantly higher in several instances. This applies for the variables CPO, IPO, PY, FMD, PXT, SIR, LIR, EXR. Variables which seem less sensitive to different coordinator's policies are UR, TB, SSHR, DTCR, DTHR, SUB. In addition, it appears that for the coordinator targeting a Community-wide low unemployment rate (Bottom-Up) is as efficient as targeting a higher one (Top-Down).

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[17] The type of policy of the coordinator precedes that of the individual countries. In terms of the model's transmission structure of information, mon/mon and mon/keyn refer to Top-Down policies of the coordinator while keyn/keyn refers to Bottom-up policies.

[18] In a related paper the situation is analyzed where the coordinator follows Keynesian policies in a Top-Down manner, irrespective of what policies the countries are pursuing (Weeren, Plasmans, Douven, VanderWal, Engwerda, 1992).

Table 6 Theil inequality coefficients target variables

		DB	FR	IT	NL	BE	UK	IR	DK	HE	PO	ES	EC
C		0.06	0.07	0.51	0.11	0.03	0.15	0.08	0.04	0.06	0.06	0.21	0.06
P		0.06	0.25	0.86	0.42	0.05	0.05	0.08	0.12	0.04	0.12	0.32	0.53
O		0.06	0.07	0.51	0.11	0.03	0.15	0.08	0.04	0.06	0.06	0.21	0.06
		0.06	0.25	0.86	0.42	0.05	0.05	0.08	0.12	0.04	0.12	0.32	0.51
I		0.32	0.05	0.51	0.20	0.20	0.12	0.49	0.25	0.11	0.18	0.57	0.19
P		0.27	0.11	0.59	0.43	0.80	0.06	0.23	2.86	0.26	0.13	2.70	0.60
O		0.32	0.05	0.51	0.19	0.21	0.12	0.49	0.25	0.11	0.19	0.57	0.24
		0.27	0.12	0.59	0.43	0.80	0.06	0.23	2.84	0.26	0.12	2.71	0.60
X		0.09	0.20	0.24	0.05	0.07	0.13	0.06	0.08	0.35	0.54	0.21	0.08
T		0.06	0.17	0.07	0.20	0.14	0.28	0.12	0.15	0.43	0.34	0.12	0.47
O		0.09	0.20	0.24	0.05	0.07	0.13	0.06	0.08	0.35	0.54	0.21	0.07
		0.06	0.17	0.06	0.20	0.14	0.28	0.12	0.15	0.43	0.34	0.12	0.47
M		0.27	0.15	0.31	0.04	0.14	0.15	0.37	0.12	0.03	0.10	1.17	0.09
T		0.18	0.08	0.27	0.03	0.10	0.07	0.36	0.08	0.02	0.12	1.60	0.61
O		0.27	0.15	0.31	0.04	0.15	0.15	0.37	0.12	0.03	0.10	1.17	0.09
		0.18	0.08	0.27	0.03	0.10	0.07	0.36	0.08	0.02	0.12	1.59	0.59
		0.12	0.08	0.01	0.00	0.02	0.06	0.32	0.03	0.27	0.20	0.91	0.15
P		0.05	0.20	0.13	0.43	0.14	0.10	0.19	0.04	0.24	0.18	1.58	0.02
Y		0.12	0.08	0.01	0.00	0.02	0.06	0.32	0.03	0.28	0.20	0.90	0.15
		0.05	0.20	0.13	0.43	0.14	0.10	0.19	0.04	0.25	0.18	1.58	0.03
		0.00	0.09	0.04	0.01	0.00	0.00	0.18	0.00	0.05	0.08	0.04	0.00
U		0.00	0.04	0.03	0.01	0.01	0.00	0.24	0.02	0.03	0.08	0.04	0.00
R		0.00	0.09	0.04	0.01	0.00	0.00	0.18	0.00	0.05	0.08	0.04	0.00
		0.00	0.04	0.03	0.01	0.01	0.00	0.24	0.02	0.03	0.08	0.04	0.00
F		0.10	0.06	0.32	0.10	0.22	0.12	0.43	0.46	0.91	0.28	0.68	0.20
M		0.06	0.07	0.67	0.42	0.35	2.37	0.16	0.76	1.22	0.36	0.41	0.52
D		0.10	0.06	0.33	0.10	0.22	0.12	0.43	0.46	0.91	0.28	0.67	0.22
		0.06	0.08	0.67	0.42	0.35	2.40	0.15	0.75	1.22	0.36	0.40	0.22
P		0.22	0.05	0.11	0.14	0.13	0.35	0.36	0.05	1.37	0.06	0.80	0.08
X		0.13	0.12	0.26	0.25	0.34	0.54	0.65	0.21	1.87	0.19	1.35	0.10
T		0.22	0.05	0.11	0.14	0.12	0.35	0.36	0.05	1.37	0.06	0.80	0.08
		0.13	0.12	0.26	0.25	0.34	0.54	0.64	0.21	1.85	0.19	1.34	0.09
		0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T		0.13	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
B		0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.13	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01

Table 7 Theil inequality coefficients control variables

		DB	FR	IT	NL	BE	UK	IR	DK	HE	PO	ES	EC
S		0.12	0.03	0.01						0.13	0.33		
I		1.23	0.05	0.07						0.13	0.11		
R		0.12	0.03	0.01						0.13	0.33		
		1.23	0.05	0.07						0.13	0.18		
L					0.06	0.01	0.05	0.18	0.13			0.20	0.28
I					0.48	0.13	0.04	0.13	0.28			0.25	0.86
R					0.06	0.01	0.05	0.18	0.13			0.20	0.70
					0.49	0.12	0.04	0.13	0.28			0.25	0.42
E		0.06	0.05	0.04	0.07	0.10	0.40	0.07	0.24	0.40	0.22	0.29	
X		0.19	0.10	0.40	0.39	0.60	0.92	0.17	0.24	0.21	0.22	0.59	
R		0.06	0.05	0.04	0.07	0.10	0.40	0.07	0.24	0.40	0.22	0.29	
		0.19	0.10	0.41	0.39	0.59	0.92	0.17	0.24	0.21	0.22	0.59	
W		0.08	0.91	0.42	0.31	0.09	0.06	2.46	0.12	5.16	1.48	0.13	0.14
G		0.20	0.15	0.51	0.37	0.07	0.33	3.30	0.10	2.53	0.18	0.16	0.06
U		0.08	0.91	0.42	0.31	0.09	0.06	2.44	0.12	5.13	1.48	0.13	0.12
		0.21	0.15	0.51	0.37	0.07	0.33	3.25	0.10	2.47	0.18	0.16	0.07
		0.00	0.19			0.00		0.01	0.00	0.04	0.15	0.01	0.04
N		0.01	0.05			0.00		0.01	0.00	0.03	0.06	0.01	0.02
G		0.00	0.19			0.00		0.01	0.00	0.04	0.15	0.01	0.04
		0.01	0.05			0.00		0.01	0.00	0.03	0.06	0.01	0.02
I		0.27	0.33		0.00	0.01	0.04	0.20	0.02	0.00	0.01	0.09	0.53
T		1.06	0.79		0.01	0.03	0.02	0.15	0.02	0.00	0.01	0.15	0.81
R		0.27	0.33		0.00	0.01	0.04	0.20	0.02	0.00	0.01	0.09	1.30
		1.06	0.79		0.01	0.03	0.02	0.15	0.02	0.00	0.01	0.15	0.31
S						0.00		0.00		0.00	0.00		
S						0.00		0.00		0.00	0.00		
H						0.00		0.00		0.00	0.00		
R						0.00		0.00		0.00	0.00		
D		0.00		0.01	0.02			0.00	0.03	0.00			0.00
T		0.00		0.02	0.05			0.00	0.14	0.01			0.01
C		0.00		0.01	0.02			0.00	0.03	0.00			0.00
R		0.00		0.02	0.04			0.00	0.14	0.01			0.01
D							0.00	0.00					
T							0.00	0.00					
H							0.00	0.00					
R							0.00	0.00					
S		0.02			0.03	0.00		0.23	0.02			0.02	
I		0.02			0.09	0.01		0.23	0.07			0.06	
B		0.02			0.03	0.00		0.23	0.02			0.02	
		0.02			0.09	0.01		0.23	0.07			0.06	

1st: Top-down (mon/keyn)
2nd: Bottom-up (keyn/keyn)
3rd: Constrained Top-down
4th: Constrained Bottom-up

Let us look more closely to the behaviour of inflation. It can be seen that the majority of EC countries is closer to the desired, Keynesian, inflation rates if the coordinator follows tight (=Top-Down) monetary policies. Would the coordinator instead shift to the same expansive Keynesian policies as the individual countries (i.e. keyn/keyn), inflation rates in the EC are pushed up above their targets. Moreover, the Theil coefficients regarding EXR reveal that these keyn/keyn policies result in devaluations of several EMS currencies against the D-mark. In other words, if not only the German anti-inflation anchor, but also that of the coordinator is raised, it appears very difficult to return even to "Keynesian" inflation rates; at the same time EMS exchange rate stability decreases. These results imply that the Council's policies have substantial impact on the inflation performance of the individual countries. We can conclude that, in this hierarchical framework, the Council mitigates inflation. Figures 3 to 8 in Appendix D illustrate this too. Here, for four big and two small countries the optimal inflation rates under each type of policy is shown. The general result emerging from these figures is that mon/mon policies produce the lowest inflation. The next lowest are mon/keyn policies while the keyn/keyn scenario generates the highest inflation rates. To put it differently: a country's shift to Keynesian policies produce higher inflation, given unchanged policies of the coordinator; and a shift to Keynesian policies of the coordinator generate higher inflation too, given unchanged policies of the countries. This conclusion should be accompanied by some comments.

First, for France the picture is different. If the Council follows a Keynesian policy too, this results in 1991, as one would expect, in the highest inflation rate for the three scenario's. However, the next year inflation plunges to zero while in the rest of the planning period it keeps below the optimal inflation paths of the other two scenario's.

Second, in general the inflation difference between the mon/mon and the mon/keyn scenario's is smaller than between one of these and the keyn/keyn one. This is illustrated for France, the Netherlands and Belgium. This is mainly due to the fact that the countries' desired inflation rates in the mon/keyn setting, although uniformly higher, have more in common with the ideal inflation rates in the mon/mon scenario. One should bear in mind that in the keyn/keyn scenario desired inflation of the Council takes into account relatively high inflation rates in Italy, the United Kingdom, Portugal and Spain. This exogenous effect works through in the model's structural equations where inflation of the EC area is an explanatory variable.

Third, inflation rates in Germany confirm the general pattern sketched above. However, German prices increase at a faster rate than in some other countries (like the Netherlands and France). After 1993, in the mon/mon scenario the inflation rate levels off, while in the expansive keyn/keyn case inflation still continues.

Equally as interesting is the performance of different policies with respect to unemployment. As we saw in Table 6, Theil unemployment coefficients for each of the four different structures of

information transmission do not differ much per country (probably with the exception of France). This implies that individual nations can attain their ambitious employment targets quite irrespective of which policy the Council implements. So we can conclude that the impact of the Council's policies is much greater as far as the fight against inflation is concerned. Optimal unemployment, however, is sensitive to different *countries'* policies. This is illustrated in Figures 9 to 14 in Appendix E where we compare mon/mon with mon/keyn policies for four big and two small countries. We observe that optimal unemployment paths in *both* scenario's are very close to their desired evolution. This applies in particular to Belgium, the Netherlands, the United Kingdom, Italy and (after 1991) Germany. Further we note that policies to lower unemployment (i.e. countries follow Keynesian instead of EMU policies) are effective for all countries. In other words, if countries prefer lower unemployment rates, they will achieve them.

7 Conclusion

In this paper we presented preliminary results of the macroeconomic effects of different policy coordination schemes within the European Community. In doing so, we used a hierarchical optimal control framework. We argue that this alternative approach to the coordination issue in Europe may suit as a first approximation to evaluate the EC's stratified decision-making process. Since, at this moment, it is not clear how the Council together with the European Commission determine desired values for their targets as well as for their instrumental variables, we presented the simulation results for four different information transmission schemes, ranging from a Top-Down to a Bottom-Up information structure.

Also in another sense this approach might be considered as useful. Common "intergovernmental" coordination devices have a noncommittal character. As a result, dishonest behaviour of individual nations cannot be excluded, and therefore jeopardizes the welfare gains of policy cooperation. On the contrary, in hierarchical control models there is a separate coordinator who is responsible for the economic performance of the aggregate. This implies that also the absolute dimension of policy coordination is taken care of. In the underlying econometric model this dimension was incorporated by letting the countries' endogenous variables also depend upon the targets of the Council.

Because it is conceivable that in the near future more macroeconomic instruments will be available at the level of the Council *casu quo* the European Central Bank, we placed some instruments at the coordinator's disposal. Notwithstanding the "hierarchical" nature of this approach, the Council implements his policies in a market-conform way. We deliberately avoided any command pressure from the 'higher' to the 'lower' authorities. Also, we did not touch, and did

not model, the political aspect of empowering the Council with macroeconomic instruments. If some countries are anxious about more power at "Brussels", this will have to be taken into account in their welfare loss functions.

The main conclusion, which gives at the same time an answer to the problem posed in this paper is, that the EC, acting as a separate coordinator, has an important, independent, macroeconomic role to play in the transition to the third stage of EMU. This applies in particular to monetary variables like inflation, nominal interest rates, exchanges rates and the money supply. We found that, for most EC countries, the convergence tests can be met if the Council follows a Top-Down policy, i.e. a tight monetary policy, instead of a Bottom-Up policy which targets the average inflation in the EC. In particular, results of the EMU-scenario show that the optimal values of inflation rates, interest rates and exchange rates of the major European countries converge. This implies that stage three is, in principle, attainable for these countries. As could be expected, the less rich member states prefer less restrictive policies (i.e., a Bottom-Up approach). In the EMU-scenario it was further shown that restrictive monetary policies are consistent with achieving a reasonable economic growth and slightly declining unemployment rates in most European economies. The view that policies to meet the convergence criteria would have contractionary effects, is therefore not supported.

If instead the coordinator pursues Keynesian policies, just like the countries do (i.e. the keyn/keyn scenario), the importance of this coordinator becomes more pregnant. We found in that case that the convergence criteria to enter full monetary union are out of range for all countries. So this underlines the potential anchor-function of the Council. If, on the other hand, the Council follows a sound anti-inflationary monetary policy for the whole EC-area, our results indicate this policy is capable to mitigate inflationary impulses stemming from Keynesian national policies (i.e. the mon/keyn scenario). Within this framework, we conclude therefore that the coordinator's policies in the monetary field are of substantial influence on the countries' abilities to move to the final stage of EMU.

In contrast, this kind of "counterveiling power" is almost absent for most countries regarding unemployment targeting. We found that, no matter what policy the coordinator implements, it were the countries themselves which have by far the greatest impact on their own desired unemployment targets.

A limitation of this approach is that only indirect economic interactions between the countries are modelled. Because this does not fit with reality, research is planned to weaken this assumption. It will also be fruitful to improve this coordination approach by refining the model (e.g. including a budget constraint and government debt variables) as well as introducing dynamic game theory. These extensions will be discussed in subsequent papers.

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Appendix A Desired Paths for the EMU Scenario

In this appendix the desired paths for the more important variables in the EMU scenario are shown like inflation (PY), unemployment (UR), the (growth rate of the) money stock (FMD), the short-term interest rate (SIR), the long-term interest rate (LIR), the US-dollar exchange rates (EXR), the wage compensation of government employees (WGU) and the total employment at the general government (NG). Although the planning period is 1986-1995, we omitted below the years 1986-1990 because for that subperiod we assumed realized values instead of typical scenario values (which start from 1991).

a) GDP's deflator (PY):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC
1991	2	2½	5½	2	3	5½	4½	3½	13	11	5½	2
1992	2	2½	5	2	2½	5	4	3	12	10	5	2
1993	2	2	4½	2	2½	4½	3½	2½	11	9	4½	2
1994	2	2	4	2	2	4	3	2	10	8	4	2
1995	2	2	3½	2	2	3½	2½	2	9	7	3½	2

b) Unemployment (UR):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC
1991	5.3	6	6	6	7	6½	11	5.1	5½	5½	12	8.9
1992	5	5	5	5	6	5½	9½	5	5	5	10	9
1993	5	5	5	5	5½	5½	9½	5	5	5	10	9
1994	4½	5	5	4½	5½	5½	9½	5	5	4½	9½	8½
1995	4	5	5	4	5	5½	9½	5	5	4	9	8

c) **Money Stock (FMD, growth rate):**

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC
1991	5	4½	7½	6	6	8½	8½	7½	16	14	8½	6
1992	5	4½	7	6	6	8	8	7	15	13	8	6
1993	5	4½	7	6	6	8	7½	6½	14	12	7½	6
1994	5	4½	6½	6	6	7½	7	6	13	11	7	6
1995	5	4½	6½	6	6	7½	6½	6	12	10	6½	6

d) **Short-term Interest Rate (SIR):**

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC
1991	6	6½	9½	6	7	9½	8½	7½	17	15	9½	6
1992	5½	6	8½	5½	6	8½	7½	6½	15½	13½	8½	5½
1993	5	5	7½	5	5½	7½	6½	5½	14	12	7½	5
1994	4½	4½	6½	4½	4½	6½	5½	4½	12½	10½	6½	4½
1995	4	4	5½	4	4	5½	4½	4	11	9	5½	4

e) **Long-term Interest Rate (LIR):**

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC
1991	8	8½	11½	8	9	11½	10½	9½	19	17	11½	8
1992	7½	8	10½	7½	8	10½	9½	8½	17½	15½	10½	7½
1993	7	7	9½	7	7½	9½	8½	7½	16	14	9½	7
1994	6½	6½	8½	6½	6½	8½	7½	6½	14½	12½	8½	6½
1995	6	6	7½	6	6	7½	6½	6	13	11	7½	6

f) **US-Dollar Exchange Rates (EXR):**

	DB	FR	IT	NL	BE	UK
1991	1.66	5.64	1241	1.87	34.16	0.57
1992	1.66	5.57	1242	1.87	34.24	0.56
1993	1.66	5.57	1242	1.87	34.24	0.56
1994	1.66	5.57	1242	1.87	34.24	0.56
1995	1.66	5.57	1242	1.87	34.24	0.56

	IRL	DK	HE	PO	ES	EC
1991	0.62	6.4	182.06	144.35	103.93	0.81
1992	0.62	6.33	200.27	155.9	107.9	0.81
1993	0.62	6.33	218.29	166.81	107.9	0.81
1994	0.62	6.33	235.75	176.82	107.9	0.81
1995	0.62	6.33	252.25	185.67	107.9	0.81

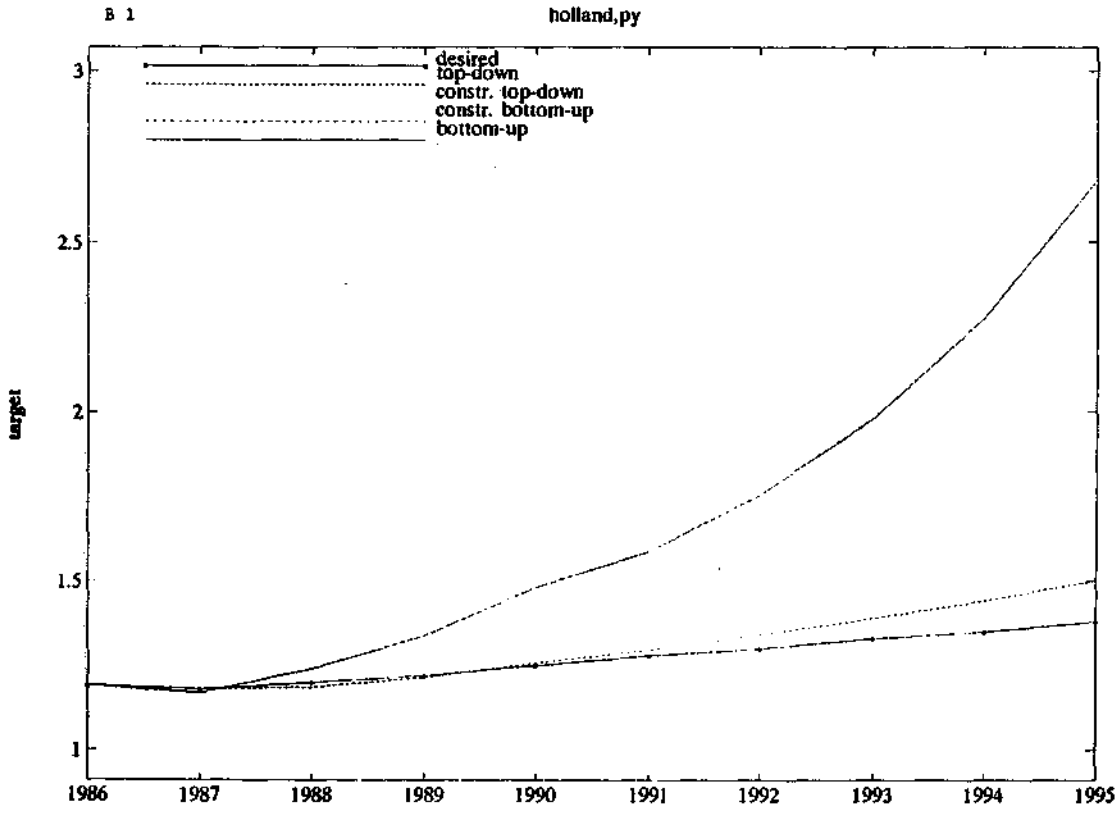
g) Wage Compensation of Government Employees (WGU):

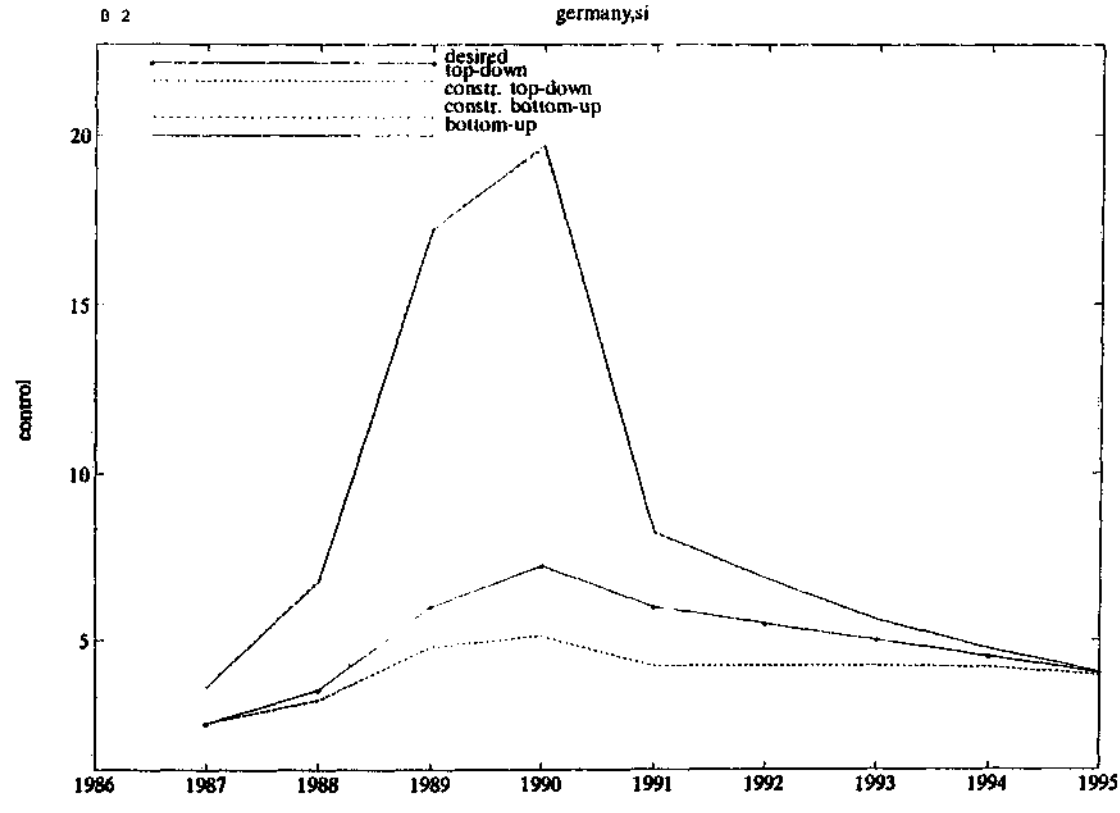
	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC
1991-1995:	increases yearly with national rates of inflation (ad a)											

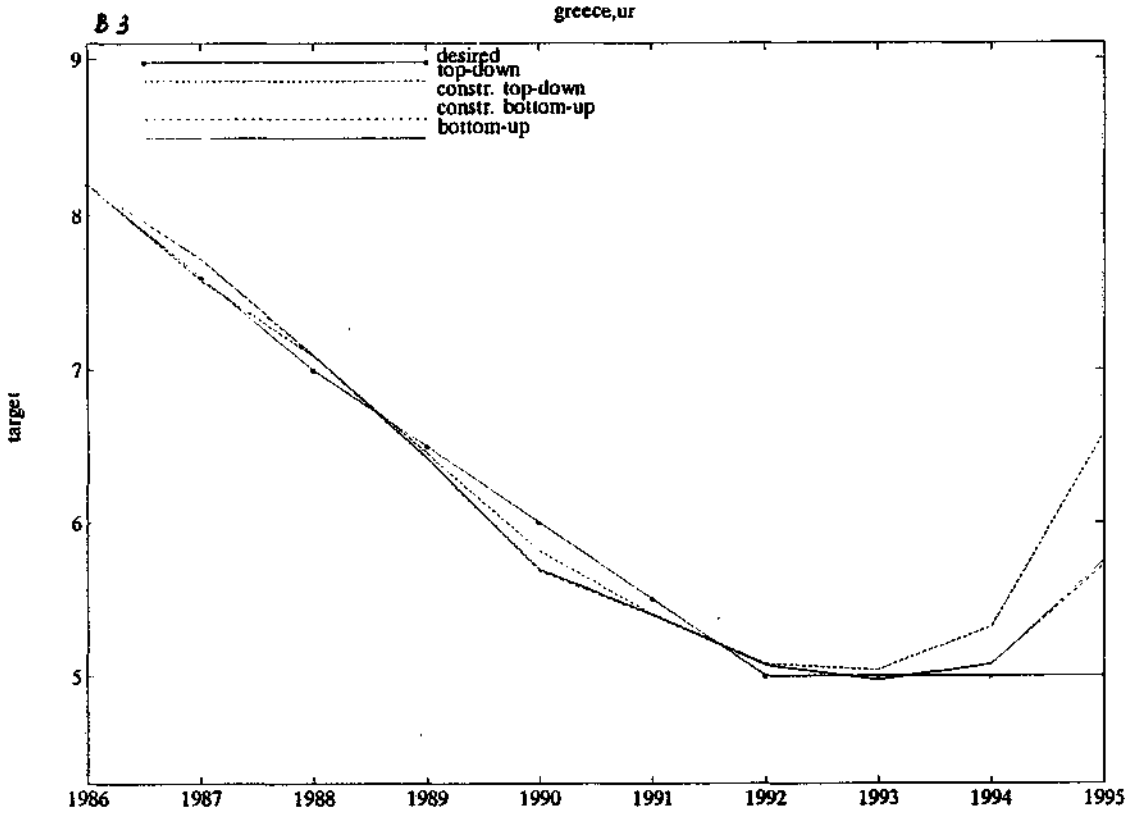
h) Total Employment at the General Government (NG)

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC
1991-1995:	no increase in numbers since 1990											

Appendix B Some countries' results



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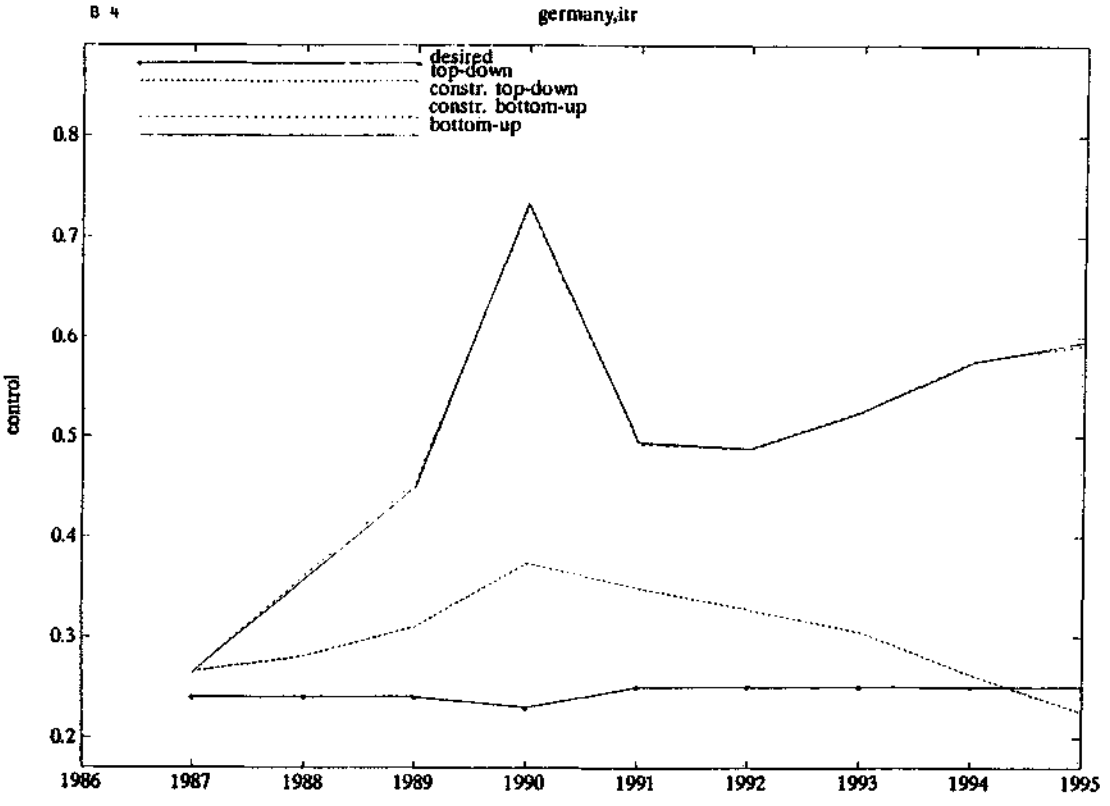
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Appendix C Desired Paths for the Keynesian Scenario

In this appendix desired Keynesian paths for those variables are shown which are different from the EMU scenario, i.e. the rate of inflation (PY), unemployment (UR), the (growth rate of the) money stock (FMD), the short-term interest rate (SIR), the long-term interest rate (LIR), the wage compensation of government employees (WGU) and the total employment at the general government (NG).

a) GDP's deflator (PY):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC [1]
1991-1995 yearly:	+4%	+4%	+6%	+4%	+4%	+6%	+5%	+4%	+13%	+11%	+6%	+5.03%

b) Unemployment (UR):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC [1]
1991	5	6	6	6	7	6½	11	5	5½	5½	12	6.36
1992	4½	5½	5½	5	6	5½	10	4½	5	5	10	5.61
1993	4	5	5	4½	5	5	9	4	4½	4½	9	5.05
1994	3½	4½	4½	4	4½	4½	8	3½	4	4	8	4.51
1995	3	4	4	3½	4	4	7	3	3½	3½	7	3.96

c) Money Stock (FMD, growth rate):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC [1]
1991-1995 yearly:	+7%	6½%	8½%	7%	7%	9%	7½%	6½%	19%	17%	9%	7.89%

[1] Calculated as a weighted average (i.e. Bottom-Up policy)

d) Short-term Interest Rate (SIR):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC [1]
1991/ 1995	6	6½	9½	6	7	9½	8½	7½	17	15	9½	7.88

e) Long-term Interest Rate (LIR):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC [1]
1991/ 1995	8	8½	11½	8	9	11½	10½	9½	19	17	11½	9.88

g) Wage Compensation of Government Employees (WGU):

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC [1]
1991-1995 yearly:	+4½%	4½%	6½%	4½%	4½%	6½%	5½%	4½%	13½%	11½%	6½%	5.53

h) Total Employment at the General Government (NG)

	DB	FR	IT	NL	BE	UK	IRL	DK	HE	PO	ES	EC [1]
1991-1995 yearly:	+½%	+½%	+½%	+½%	+½%	+½%	+½%	+½%	+½%	+½%	+½%	+½%

1) Calculated as a weighted average (i.e. Bottom-Up policy)

Appendix D Inflation rates under three policy scenario's

Figure 3 Optimal inflation in Belgium

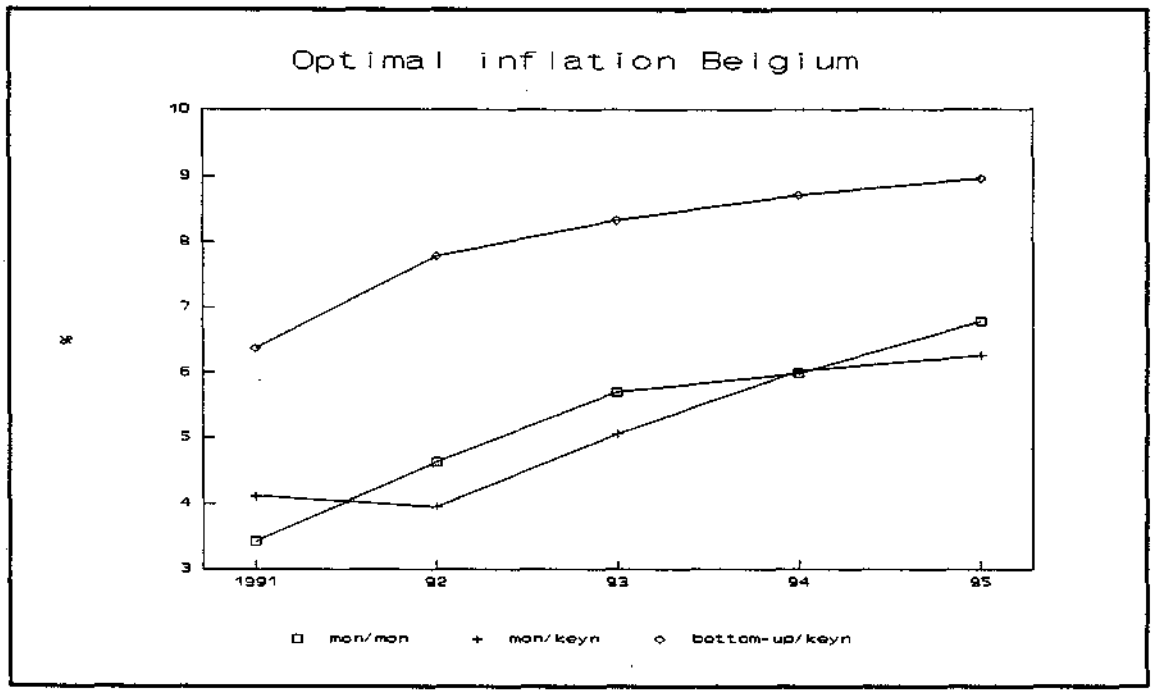
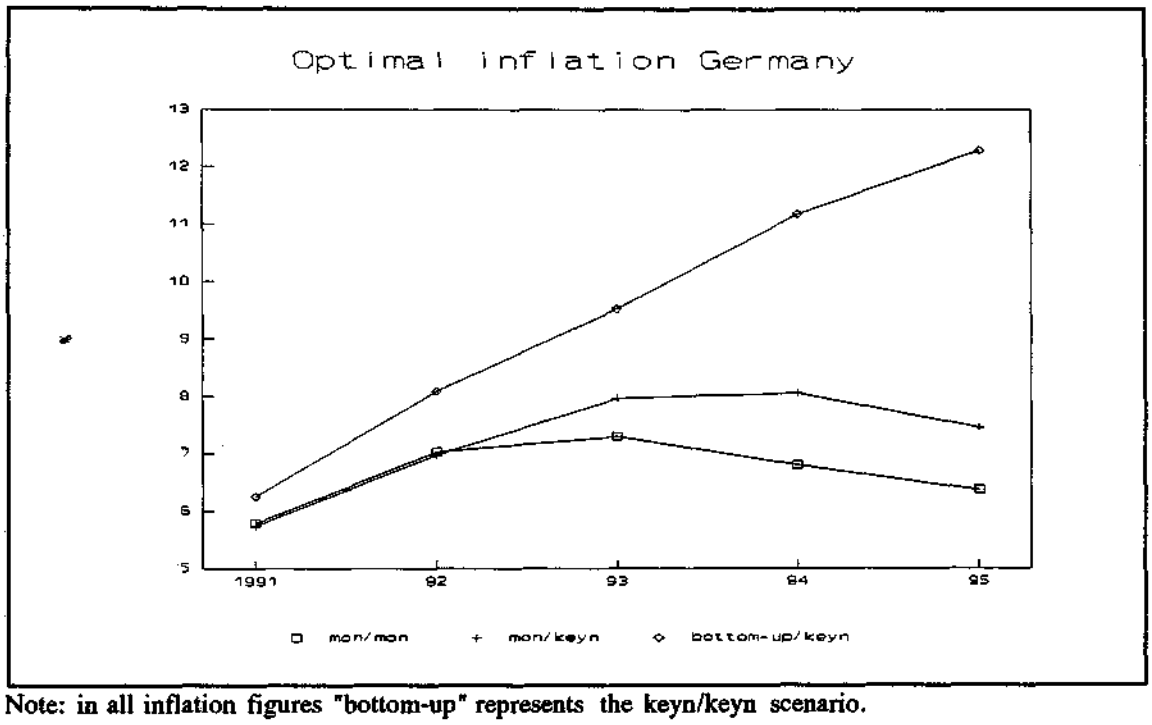


Figure 4 Optimal inflation in Germany



Note: in all inflation figures "bottom-up" represents the keyn/keyn scenario.

Figure 5 Optimal inflation in France

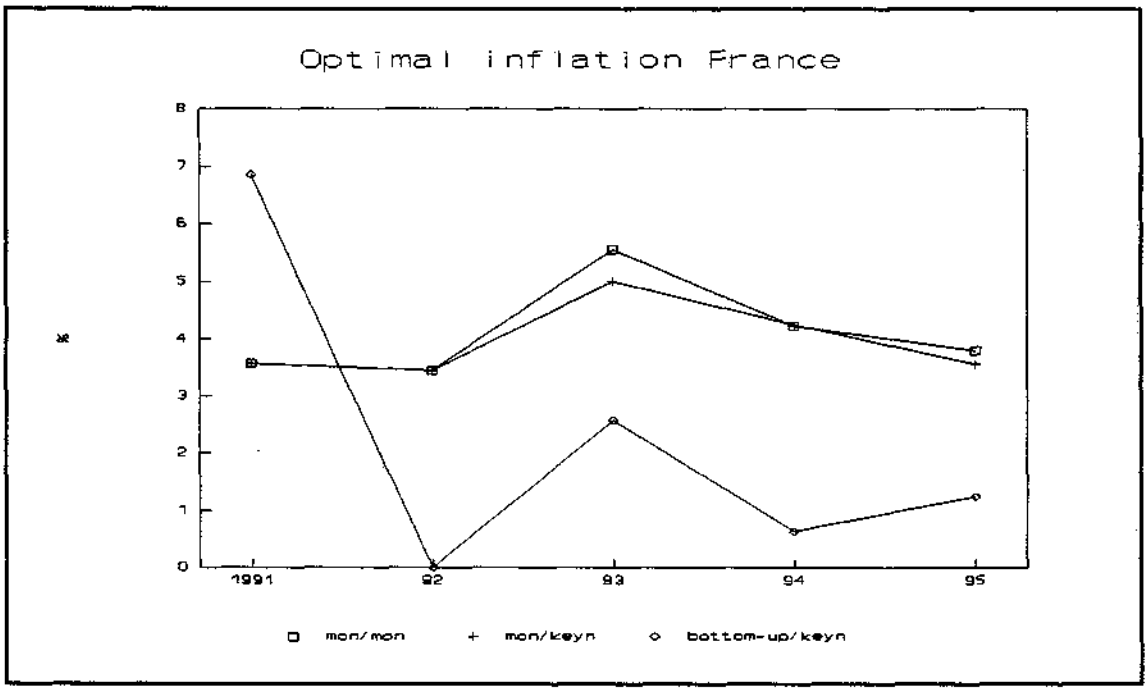


Figure 6 Optimal inflation in Italy

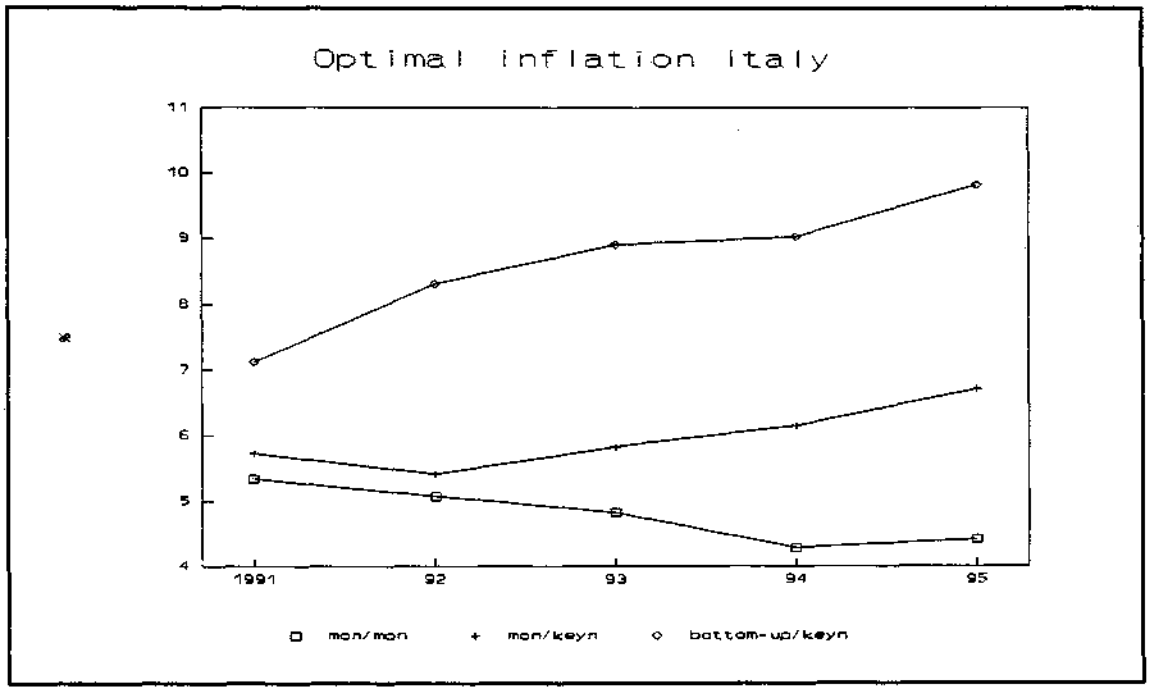


Figure 7 Optimal inflation in The Netherlands

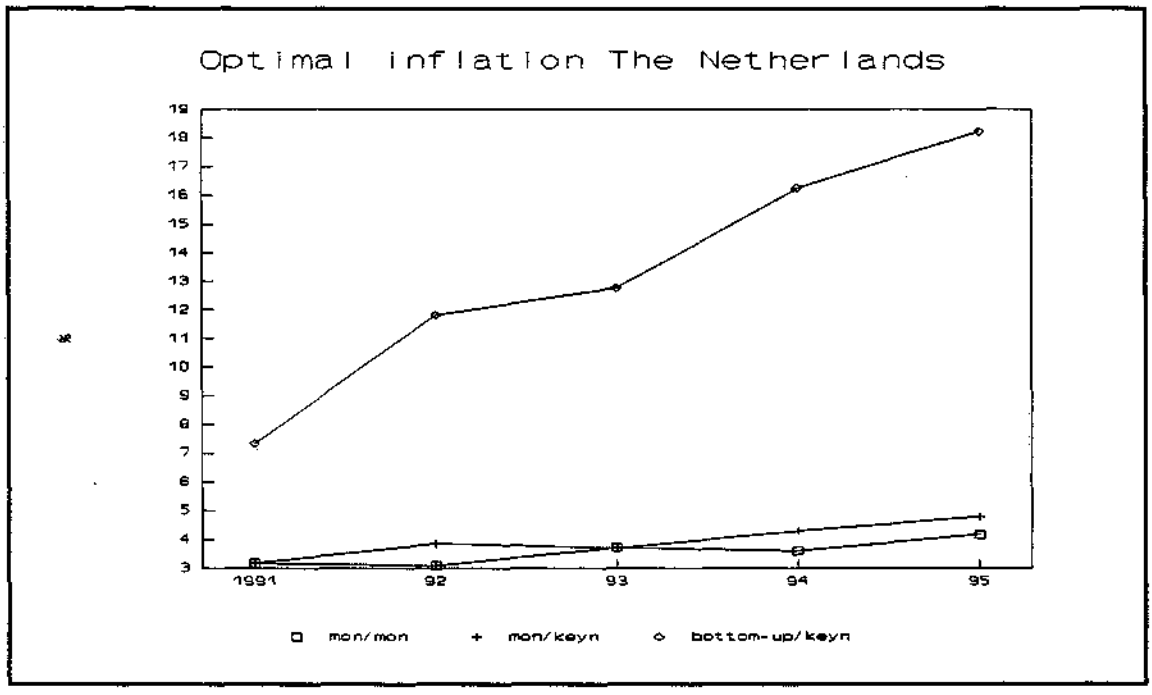
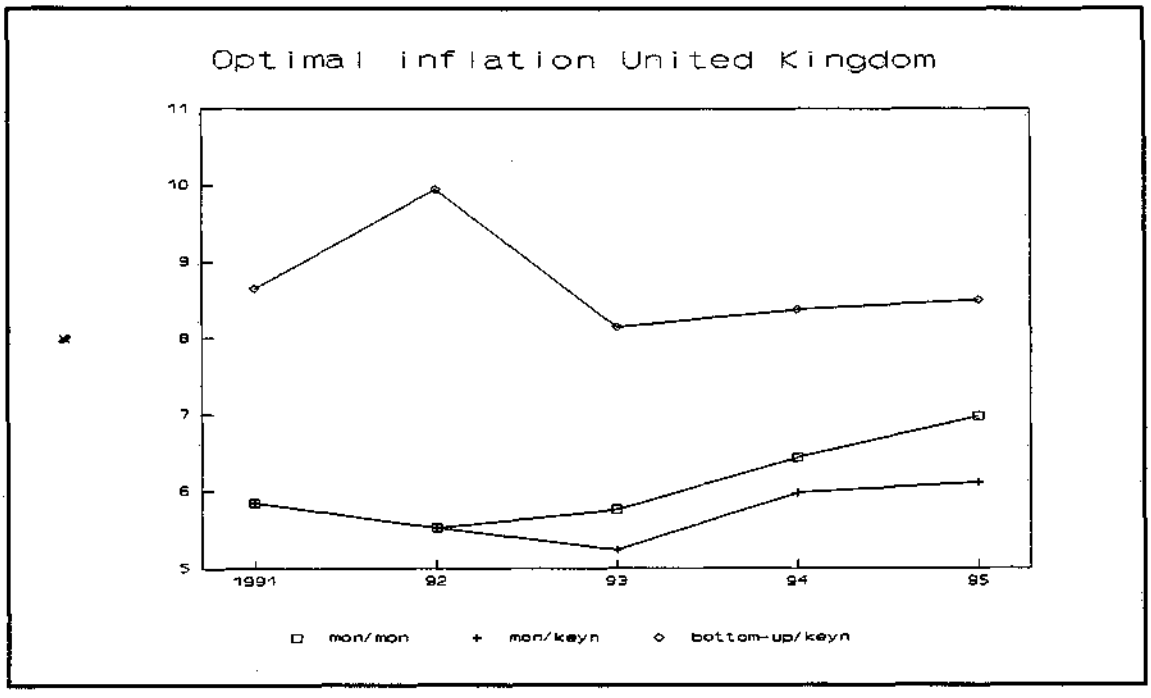


Figure 8 Optimal inflation in the United Kingdom



Appendix E Unemployment rates under two policy scenario's

Figure 9 **Desired and optimal unemployment in Belgium**

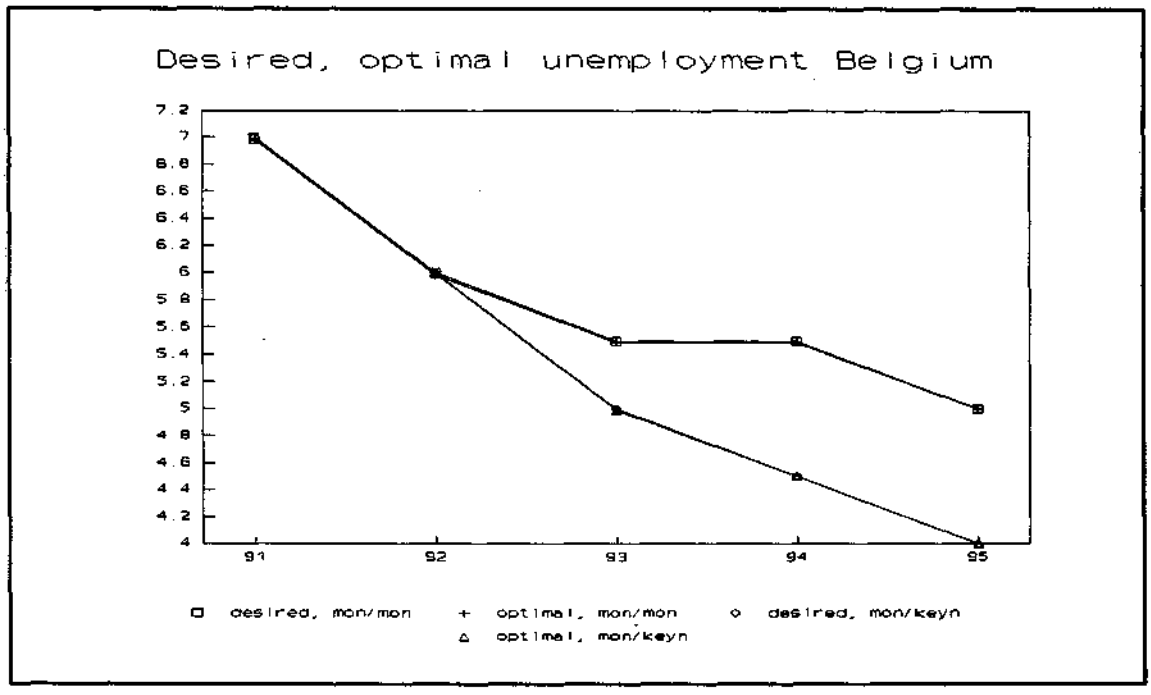


Figure 10 **Desired and optimal unemployment in Germany**

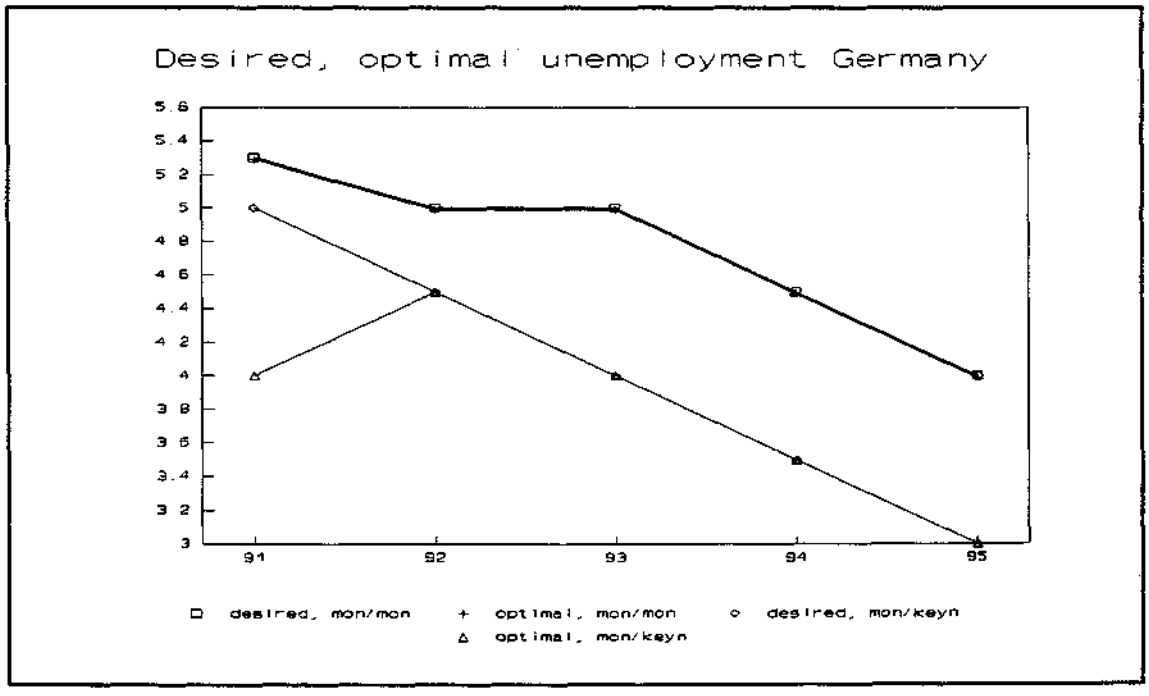


Figure 11 Desired and optimal unemployment in France

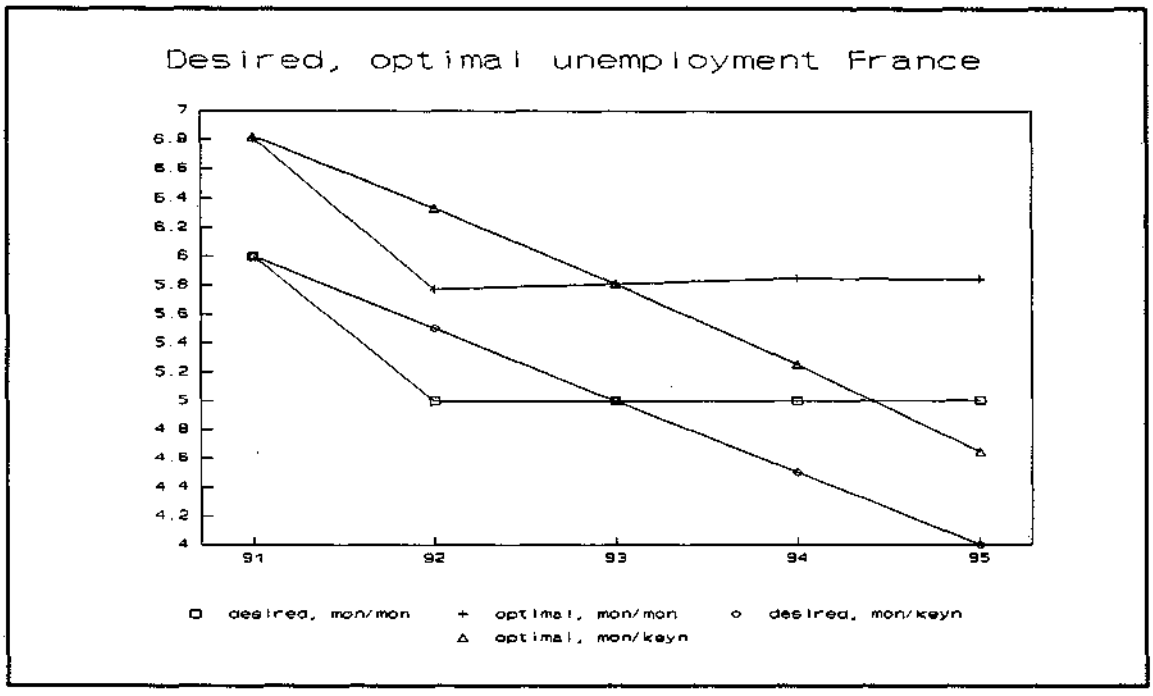


Figure 12 Desired and optimal unemployment in Italy

Figure 13 Desired and optimal unemployment in The Netherlands

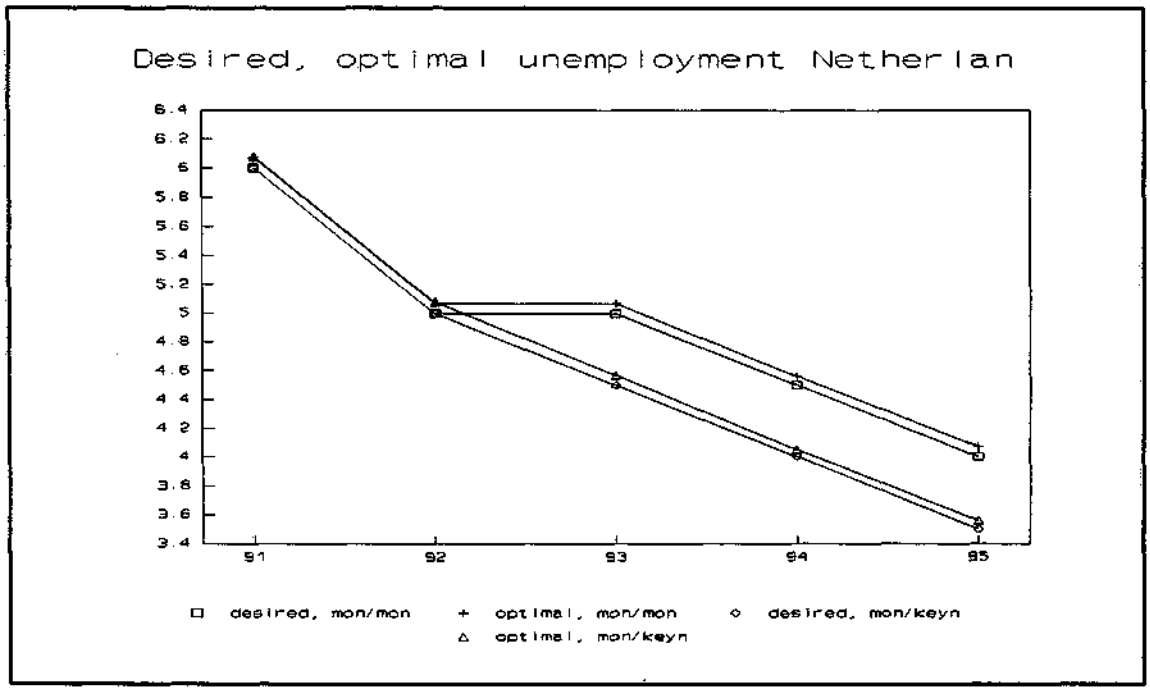


Figure 14 Desired and optimal unemployment in the United Kingdom