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S.L.I.M.
A Small Linear Interdependent Model of eight EU-Member States, the USA and Japan

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Abstract

In this paper we present a small estimated multi-country model of eight EU-Member States (Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands and the United Kingdom), the USA and Japan, in which international linkages are directly modelled. Our starting point is a modified version of the theoretical two-country Mundell-Fleming model. This model is extended in three ways. First, it is extended to more than two countries using the principal trading pattern of each individual country. Second, we extended the model by including country-specific labour market characteristics, wage-price spirals and long term interest rates. Third, we included dynamic responses into the model which makes it possible to distinguish between short- and long-run behaviour of the economy. In each country direct linkages are modelled through outputs, prices, exchange rates and interest rates. For estimation we use annual data for the sample period 1960-1991. This estimation process is based on partial adjustment and error-correction arguments. Historical simulations and shock analysis are performed to show various properties of the model and the outcomes of the model are compared with those for existing models in literature. Due to its linearity and the strong international linkages, the model is also suited for dynamic game applications.

Keywords: multi-country model, direct linkages, historical tracking performance, fiscal and monetary shocks.
JEL-codes: F42, F47

S.L.I.M. - A Small Linear Interdependent Model of eight EU-Member States, the USA and Japan

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1 Introduction

The aim of this paper is to build a small linked multi-country model of eight EU-Member States (Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands and the United Kingdom), the USA and Japan. The model contains six linear behavioural equations for each country and is estimated using annual data for the sample period 1960-1991. The eight EU-Member States represent economies in the European Union for which there is a growing mutual economic activity and for which the annual data, used for estimation, are (almost) completely available. The USA and Japan are included in the model because they are the most important countries outside the

EU with the strongest impact on the EU-countries. Due to the increasing integration process between (especially) the EU-countries, external effects will become more and more important. In the model we will focus our attention especially on these external effects, which are modelled through direct linkages. The links between the countries considered are of various types. We will include in the model financial links such as interest rates and exchange rates, links between price variables such as consumer prices and GDP-prices and links between volume variables such as output volumes. The economic functioning of the individual economies and their links will be explained in this paper by carrying out simulation experiments and shock analyses.

There is still a debate in the literature for multi-country studies about the direction (and also strength) of the impact of external effects. In an overview of multi-country modelling Hickman [17] reports of various early multi-country studies where some external effects are investigated. The first research projects on this issue led to the general finding of rather weak spillover effects to other countries from disturbances originating even in large countries. It seems that even today this view has not changed very much. Buiter et all. [6] report the same findings: "Economic multi-country models for simulation imply that under the ERM the output and interest rate effects of a fiscal expansion are confined mostly to the originating EC-country and that the international spillover effects will be insignificant". Furthermore, they quote Bryant et al. [5] who claim that even the sign of a spillover effect is likely to be ambiguous. In a comparative study of five multi-country models, Whitley [26] finds also that in these models spillover effects to the other European countries, originating from single-country European expansion, are negligible. In the case of a fiscal expansion, Whitley reports some quantitative figures of spillover effects: "Spillover effects to the other European countries are largest in MIMOSA (a multi-country model used by the Observatoire Français des Conjonctures Economiques (OFCE) and Centre D'Etudes Prospectives et D'Informations Internationales (CEPII)), where the increase in GDP in the other countries following a shock in Germany or the United Kingdom is some 20% - 30% of the increase in output in the country shocked; comparable estimates for the other models are around 10%". Whitley also reports figures of the effects on EU-countries of a fiscal expansion originating in the USA. The increase in GDP in the EU-countries following a shock in the USA is on average somewhat higher than 10% of the increase in output in the USA. Again, Whitley finds higher figures which range between 20% and 30% for the MIMOSA model.

It is clear that to exactly reveal the international interdependencies is not an easy task. However, the growing interdependence of the EU-economies indicates that spillovers will become more important in the future which makes it necessary to study models with stronger interdependencies. A priori, e.g., one would expect at least as strong spillover effects in case of an output shock originating in Germany (or another large EU-economy) on other EU-economies as, for instance, in the case of an output shock originating in the USA. There are two basic reasons for this. First, trade among EU-countries is higher than trade with the USA. Second, yearly data show strong correlations between growth output figures of the EU-countries. This last aspect may be due, for a certain part, to similar cyclical behaviour or common shocks but, nevertheless, both aspects indicate that spillover effects among EU-countries could be more important than most multi-country models suggest. Our model is specified such that foreign variables are directly linked with variables of the home country. For example, the aggregate demand equation of the home country will be directly explained by foreign variables, such as foreign output/aggregate demand, the exchange rate and foreign output prices. So, our model does not contain particular export or import categories. This does not necessarily imply that our model is inferior to the large multi-country models, which distinguish many more categories. For instance, in the case of aggregate demand, in our simple model a broad measure such as foreign output/demand represents also indirect effects such as foreign investments and knowledge spill-overs. Such spillovers among countries are better captured by a broad measure such as foreign output/demand than by parts of output such as export or import figures.

Since, we want to use the model for dynamic game experiments we decided to construct a linear model initially. The theoretical starting point will be a modified version of the theoretical Mundell-Fleming model (see, e.g., McKibbin and Sachs [18]). The advantage of this framework is that it is small and linear and that direct linkages are already in the model. The theoretical model is introduced as an equilibrium model between two countries. We extend this two-country model to more countries using the principle trading pattern of each individual country. As argued by Wallis [25] comparative modelling seems to be the major way to improve macroeconometric models; therefore our model will be compared to other multi-country models. We apply the same shocks to our model as Whitley [26] applies to the multi-country models in his comparative study.

The organisation of the paper is as follows. In section two we introduce the theoretical model. Furthermore, we explain the extension of the two-country model to a multi-country model. In section three we will explain the estimation procedure and our estimation results. Various properties of the model will be investigated in sections four and five. In section four we will present the historical tracking performance of the model. We present static, as well as dynamic, simulation results for all the endogenous variables of the model. In section five we apply shock analysis. Finally, we will present our conclusions in section six.

2 The theoretical model

As indicated in the Introduction, the starting point of our multi-country model will be a simple two-country model in the Mundell-Fleming framework. In Table 1, a modified and extended version of a theoretical two-country Mundell-Fleming model is shown (see, e.g., McKibbin and Sachs [18] for a theoretical interpretation and Papell [21] and Ghosh and Masson [13] for an estimated rational expectations version of this model.). The standard Mundell-Fleming model contains an LM-curve which is replaced by a long term interest rate equation in our model, since during the eighties the major monetary policy pursued in the various countries was an interest rate policy. Furthermore, a wage-price spiral is included in this model and, because employment is used as an explanatory variable of wages, we decided to endogenise employment. The model, described in Table 1, contains five exogenous variables: the exchange rate, government expenditure, labour force, taxes and the short term interest rate. We will use this (almost completely) static model as a starting point for building our multi-country model. In the next subsections we will describe the model and explain how the theoretical model is extended to one which can handle more than two countries.

2.1 Description of the theoretical model

The model, as defined in Table 1, refers to one (home) country. The equations for the second (foreign) country are similar. In the theoretical model, it is assumed that each country produces one (type of) good(s), which is an imperfect substitute for the other country's (type of) good(s). Both (types of) goods are tradable.

The first equation is a standard IS-curve for aggregate demand with the real long term interest rate instead of the real short term interest rate. The long term interest rate is interpreted as a measure for the cost of capital. It represents either the costs of borrowing new capital or the opportunity cost of reinvesting retained earnings in the firm. It follows from equation (1) that real aggregate demand is assumed to be a function of the real exchange rate, expressed as $(E+P_y^*-P_y)$, the real long term interest rate, real foreign demand, real government expenditure and real taxes. Important to mention is that P_y is the output price level of the only (type of) good(s) in the home-country and that E is defined as the price of one unit of foreign currency in terms of domestic currency. So, a rise in E corresponds to a depreciation of the home currency. The degree of substitutability between domestic and foreign goods enters this equation explicitly by the Y^*-

variable. Theory assumes $\alpha_i \geq 0$ for $i = 1, 2, ..., 5,$. Direct linkages between the domestic and foreign country are modelled in equation (1) through the Y^*- and P_y^*- variables and the exchange rate E.

In equation (2) the output price level is explained in a standard way. The output price level depends on factor costs, which are represented by per capita wages W of the private sector (cost-push inflation). Furthermore, the output price level depends on foreign prices, indicated by $(E + P_y^*)$, and the deviation of gross domestic product from its trend output $\bar{Y}$. All parameters are assumed to be positive.

Consumer prices in equation (3) are assumed to be (positive) linear combinations of domestic output prices P_y and import prices, represented here as $(E + P_y^*)$.

The labour demand function in equation (4) is determined in a fairly standard way. Three factors

Table 1: The theoretical model for one country

Equation number	*Equation*[a]
(1)	$Y = \alpha_1(E + P_y^* - P_y) - \alpha_2(RL - \Delta P_y) + \alpha_3 Y^* + \alpha_4 G - \alpha_5 T$
(2)	$P_y = \gamma_1 W + \gamma_2(E + P_y^*) + \gamma_3(Y - \bar{Y})$
(3)	$P_c = \delta_1 P_y + \delta_2(E + P_y^*)$
(4)	$N = -\eta_1(W - P_y) + \eta_2 Y + \eta_3(E + P_y^* - P_y)$
(5)	$W = \vartheta_1 P_c - \vartheta_2(U - \vartheta_3 U_{-1}) + \vartheta_4(Y - N) - \vartheta 5(P_c - P_y)$
(6)	$RL = \beta_1 RL^* + \beta_2 RS + \beta_3 \Delta(G - T) + \beta_4 \Delta P_c$
(7)	$U = L - N$

a. Variables are defined as follows (asterisks indicate foreign country variables and Δ indicates 'first differences'; all variables, except RS, RL and U which are rates, are in logarithmic form):
Y = real aggregate demand (equal to supply, measured by gross domestic product (GDP))
$\bar{Y}$ = trend volume of real gross domestic product
G = real government expenditure
T = real taxes
RS = nominal short term interest rate
RL = nominal long term interest rate
E = exchange rate defined as the nominal price in domestic currency of a unit of foreign currency
P_y = price level of aggregate demand
P_c = consumer price level
W = nominal wage per employee in the private sector
L = labour force (labour supply)
N = employment
U = unemployment rate

explain labour demand, namely, real wage costs, output and the gap between foreign and domestic prices. Output is assumed to have a positive effect on labour demand and real wage costs a negative effect. The effect of the difference between the foreign and domestic price levels is ambiguous. From the competitive point of view, if foreign firms raise their prices domestic firms will follow and raise prices as well, in order to get more profits. As a consequence there is room for hiring more labour. From the intermediate product view, a rise in the price of the intermediate (foreign) good will influence the firm's choice between labour and intermediate goods. This choice, however, depends on the production-structure of the firm. In general, we expect a negative sign.

Nominal per capita wages (of the private sector) are modelled in equation (5). They are assumed to depend positively on the consumer prices, according to a price indexing elasticity ϑ_1, and negatively on the unemployment rate, defined as the difference between the (exogenous) labour force and total employment (see definitional equation (7)). With rising unemployment, workers are more solicitous about their jobs as compared to their wages, so their wage claims will be restrained. Moreover, employers will have a larger number of employable workers at their disposal, so their wage offers can be expected to decline. The difference between the short run and the long run impact of unemployment on the nominal wage is determined by the persistence parameter ϑ_3, which reflects the vulnerability of wages to hysteresis. With proloUnged unemployment, the people unemployed can no longer be considered as strong job-candidates who can put significant pressure on the labour market (owing to the deterioration of their skills, motivation and search intensity). In the long run, the negative effect of unemployment on wages may therefore be much weaker than in the short run. Finally, the nominal per capita wages depend positively on the average labour productivity, represented by $(Y-N)$, assuming that the impact of labour productivity is involved in wage claims, and negatively on the terms of trade, represented by $(P_c - P_y)$ (see, e.g., Heylen [15]) .

Equation (6) explains the domestic long term interest rate. It is assumed that the long term interest rate is explained by the domestic short term interest rate RS, the foreign long-term interest rate RL^*, the changes of government deficit $\Delta(G-T)$ and consumer price inflation which is expressed as ΔP_c. In the sequel we will use the short term interest rate as the price of the money supply and, therefore, it will be used as a policy variable. It is clear, however, that this is a simplification, because, for many countries in a quasi-fixed exchange rate system as the EMS, the short term interest rate is, obviously, a variable which can be controlled only partially. Furthermore, it is assumed that a substantial increase in a country's government deficit will push up the long term interest rate (long term debt financing of the government). By including consumer inflation prices implying a long run relationship between ongoing inflation and (long term) interest rates, we also consider the Fisher effect.

Due to our precondition to keep the model simple, we had to choose from the outset to take certain effects not into account. For instance, the model excludes expectations, we do not assume that there is a natural rate of unemployment, there are no particular expenditure categories and the model fixes the supply of labour as being exogenous. Furthermore, at this stage, the exchange rate is assumed to be exogenous. Also, we make the simplifying assumption that aggregate demand equals aggregate supply.

In the next subsection we extend the theoretical model to one which can handle more countries. For this extension we will use the principal trading pattern of each individual country with the other countries considered in the model.

2.2 The extension of the theoretical model to more countries

In this section we discuss the extension of the model to one which can handle more than two countries. The structure of each individual country is given in Table 1. However, we have to specify now how each country's model is linked to the other countries' models. Direct linkages appear in the two-country model through the real exchange rate $(E + P_y^* - P_y)$, the real foreign aggregate demand Y^*, the foreign nominal long term interest rates RL^* and the import prices $(E + P_y^*)$. In macroeconometric modelling, the standard approach for the extension to more than two countries is to consider trade linkages, where the impact of foreign countries is linked through import prices and export and import equations (see, e.g., the Quest model [3]). An other (more simplified) method is estimating the export equations of a home country by adding (trade) weighted averages of foreign outputs (see, e.g., the Taylor model in [23, 24] where, e.g., Y^* in the export equation is replaced by a 'trade weighted average of foreign outputs'). One of the main drawbacks of these approaches is that, in these models, spillover effects among European countries, originating from a single-country European fiscal policy measure, are negligible (see Whitley [26]). A possible reason for these small effects could be that foreign effects are modelled through export or import equations and, so, indirectly influence aggregate demand. Furthermore, using trade weighted averages means that *a priori* the weight of importance of a foreign country is imposed, which can trouble the final outcome. The existence of many more international transmission effects than just trade, makes it likely that the importance of the various international linkages among countries could be different from those suggested by trade figures. The approach we select here is that we do not replace the *-variables in Table 1 by a trade weighted average of the foreign variables, but incorporate only those countries in the model which were (the most) important trading partners during the sample period 1960-1991. The inclusion of *all* the foreign countries would generate estimation problems because of our limited number of observations. So, instead of *one* $(E + P_y^* - P_y)$- or Y^*- variable in the aggregate demand equation, we got several *-variables, each implying an important foreign country for the domestic country in question. The same approach will be applied for the other equations in Table 1 which contain foreign variables. As a consequence we get different foreign variables for different countries.

Table 2: Domestic countries and their most important trading partners

Domestic country	most important trading partners
Belgium	Germany, France, Netherlands
Germany	France, Italy, USA, Japan
France	Germany, Italy, United Kingdom, USA
Denmark	Germany, United Kingdom, USA
United Kingdom	Germany, France, USA
Ireland	Germany, United Kingdom, USA
Italy	Germany, France, USA
Netherlands	Belgium, Germany, France, United Kingdom, USA
USA	Germany, Japan
Japan	Germany, USA

Table 2 presents our choice of the foreign countries which will be considered as important countries for the domestic country and which will appear as *-variables in the equations of the domestic country. In general, the countries chosen are those with the highest trade share (see, e.g., the International Financial Statistics Yearbook of the IMF for trade share figures). However, we must confess that the boundary-lines, determining which country is included as importing/exporting country, are sometimes somewhat arbitrary. For instance, we also took into account that large countries will generate more externalities (e.g., knowledge spillovers) than small countries. Hence, sometimes, a large country was favoured over a small country. For example, we excluded small countries like Belgium and the Netherlands as important trading partners of Germany and France. Furthermore, we included Japan as important trading partner of Germany. Of course, by considering for each country only its most direct linkages many of the existing (weaker) trade linkages between countries are ignored. However, as we will see later on, through the strong direct interaction among countries still (nearly) all countries will be indirectly linked.

Remark that, in our approach, we do not use trade share figures to determine the weight of importance of an effect of a relevant foreign country. In our approach the estimation procedure, which will be explained in the next section, will decide about the weight of importance of a foreign country included. By doing so, we expect to get stronger spillover effects and more differentiation between countries than found in the existing multi-country models. A disadvantage of this estimation procedure can be that multicollinearity may arise between variables of various countries, e.g., owing to similar cyclical behaviour in these countries. Furthermore, spill-overs from countries which are not explicitly modelled are supposedly reflected in the estimated effects of the trade partners which are included in the model.

In the next section we explain our estimation methodology and, finally, present the estimation results for each equation of the model.

3 Estimation

We will start this section by explaining the methodology of estimation. Thereafter, we will present in the various subsections the estimation results for each equation separately. For estimation we use yearly data from 1960 till 1991. A description of the data can be found in Appendix A.

In general, the equilibrium specification in Table 1 will be made dynamic according to an Error Correction Mechanism (ECM). In the case of one endogenous variable, e.g., y_t and one explanatory variable, e.g., x_t, the ECM representation relates the current change in y_t to the past deviation of y_t, y_{t-1}, from its long-term path $(\alpha + \beta x_{t-1})$, and to the current change in x_t, as well as to the past changes in x_t and y_t. Such ECM can be written as (see, e.g., Fuss and Sekkat [12]):

$$\begin{aligned} \Delta y_t &= \lambda(y_{t-1} - \alpha - \beta x_{t-1}) + \\ &\quad \delta_0 \Delta x_t + \delta_1 \Delta x_{t-1} + \delta_2 \Delta x_{t-2} + \ldots + \gamma_1 \Delta y_{t-1} + \gamma_2 \Delta y_{t-2} + \ldots + \epsilon_t. \end{aligned} \tag{1}$$

In equation (1), λ is called the error correction parameter and $(y_{t-1} - \alpha - \beta x_{t-1})$ the error correction term. The speed of adjustment of y_t to its long-term path is determined by λ. It must be negative and less than one in absolute value for the ECM to be stable. In the case that α and β are known, their values can be substituted into equation (1), which indentifies the remaining equation. However, α and β are unknown in most cases. Then, in order to estimate equation (1) we rewrite the long run relationship in (1) as follows:

$$\lambda(y_{t-1} - \alpha - \beta x_{t-1}) = \lambda_0 + \lambda_1 y_{t-1} + \lambda_2 x_{t-1} \tag{2}$$

The approach that we follow here is that we subsitute (2) in (1) and then estimate equation (1) in one step [1]. In our case, now, the best way to proceed would be to assume that the long-term path for each equation is specified as given in Table 1. Furthermore, we would then have to add present (and lagged) changes of each variable in the equilibrium equation of Table 1 to get an equation as specified in (1). However, obviously, if many variables enter the equilibrium equation, the amount of variables which enter the general ECM in (1) can expand quickly. In our case we have a very small data set and, therefore, we have to be very careful in selecting the variables for the ECM-model. Therefore, the approach we decided to use here, and which worked well in practice, is that only domestic variables are chosen to enter the long-term equilibrium relationship and that all variables of the equilibrium relation, specified in Table 1, will enter the general equation in difference form. Remark that with this procedure we give more weight to short-term dynamics than to long-term dynamics [2], and that through the limitation of foreign level variables the problem of 'spurious regression' is reduced.

The estimation procedure we use is the *general to specific approach*, in the sense of the Hendry-methodology (see, e.g., Hendry [14]). Considering the limited number of available observations, the general model (1) is generally overparameterized. By data-based simplification (i.e., deleting variables with inadmissible parameter impacts and, next, deleting variables with insignificant parameter estimates) the general model is reduced to a more parsimonious model. In the next subsections we specify, for each equation separately, the general dynamic relationship and the decision criteria for determining the simplified equation.

It is common use in macroeconomic modelling that, in order to get a first-shot estimate, each equation is estimated with ordinary least squares (OLS). It is generally known (see, e.g., Brandsma et al. [3]) that simultaneous estimation (e.g., 2SLS, 3SLS) adds little to explanatory power when it is already high in single equation estimations. Furthermore, we have the additional problem that in our case the number of exogenous variables exceeds the number of observations. In the case of simultaneous estimation procedures like 2SLS, 3SLS, we have the additional problem of how to

[1] For efficiency reasons we do not apply the two step procedure in which the long-term path is estimated first; see, e.g., Engle and Granger [10]

[2] Note, that with this approach we also suppress some of the impact of foreign activity.

select the appropriate set of instrumental variables. For some cases we used the 3SLS-procedure as a test (for instance in the estimation process of the wage-price spiral). In those cases where 3SLS-results did not correspond (roughly) to the OLS-outcomes, we adopted the approach that we deleted the variable which was responsible for this problem. In most cases that variable could be traced by the fact that it was significant in the OLS-estimation procedure, but insignificant in the 3SLS-estimation procedure. The problem of collinearity is circumvented as follows (see Brunia [4]). If more than one right-hand side variable is found to be significant, then a variable is only retained if it is also significant when the other variable is dropped from the equation, otherwise it is eliminated. We must stress that we applied no formal test to see whether variables which enter the long-run relationship are cointegrated or not. There are two reasons for this, which are both related to the fact of a small data set. First, the appropriate tests are asymptotically valid, but the small sample properties of these tests can be questioned (Cochrane [8]). Second, we put much emphasis on getting reasonable static and dynamic simulation results in the process of modelling. If one does so, it can happen that a good fit of a single equation turns out to be a bad equation for the final model.

We are aware of the critique on the general to specific approach that, when applying this methodology, most researchers do not give an exact description of the decisions taken when moving from a general to a simplified model (see, e.g., Pagan [20]). During the process of simplifying the general equation, there is always the interference between decision-making on statistic, economic or simulation grounds and, therefore, a lot of re-estimation has mostly taken place before the final equation is obtained. We should also notice that giving an exact description of the decision-making process of the finally obtained simplified equations for all the sixty (estimated) equations would be very space consuming and, therefore, will not be presented in this paper. Hence, we will describe our estimation procedure as clearly as possible, without going into unnecessary details of each estimation before coming up with our final results.

We will present our estimation results for each equation separately. The results are presented with belonging t-statistics, $\bar{R}^2$, the standard error (multiplied by one thousand), SE, and a statistic for (first-order) autocorrelation. Because of the occurrence of lagged dependent variables, the Durbin-Watson statistic is not an appropriate test statistic on first order autocorrelation. Therefore, we used the t-statistic on the estimated autocorrelation coefficient in the following model:

$$\hat{\epsilon}_t = \rho\hat{\epsilon}_{t-1} + \gamma' x_t + \eta_t \tag{3}$$

where $\hat{\epsilon}_t, t = 1, ..., T$, are the OLS-residuals from the originally estimated equation: $y_t = \beta' x_t + \epsilon_t$. The statistic $t(\hat{\rho})$ from the OLS-estimation of equation (3) is shown for each equation and it should be noticed that the null-hypothesis of zero autocorrelation is accepted if this statistic is smaller than 2 in absolute value. According to Kievit [19] this autocorrelation test is most useful in the case of small data-sets.

3.1 Aggregate Demand

The first equation we consider is the aggregate demand equation. This equation contains five explanatory variables. Two of these explanatory variables involve foreign variables. As explained in the previous section, each foreign variable has to be replaced by a set of foreign variables, as indicated in Table 2. As already noted, following this approach may increase the number of explanatory variables to a large extent. Since we only have a sample of 32 observations it is clear that we can only consider a subset of these variables. As explained in the introduction of this section we do not consider the foreign level variables in the estimation process. Furthermore, we excluded taxes from the estimation process, because it was not possible to find satisfying estimation results for this variable. For most countries, the data of T and G are rising in time with more or less the same speed. Therefore, running a regression which includes both variables did (most of the time) not yield an expected (positive) impact of G and a (negative) impact of T; we also tried

the combination $(G-T)$, but this did not work out as well. For three countries, USA, United Kingdom and Ireland, we used the real short term interest rate. According to the literature in the USA, United Kingdom and Ireland, mortgage interest payments are indexed to money market rates. Hence, higher money market rates can impose a significant cost on house-owners (see, e.g., for the United Kingdom and Ireland, Eichengreen and Wyplosz [9], and for the United States, Ghosh and Masson [13]).
Summarizing, we started our approach with the following general aggregate demand model for all countries:

$$\begin{aligned}\Delta Y_t = \quad & a_0 + a_1 Y_{t-1} + a_2 G_{t-1} + a_3(RL_{t-1} - \Delta P_{y_t}) + \\ & a_4 \Delta G_t + a_5 \Delta(RL_{t-1} - \Delta P_{y_t}) + a_6 \Delta Y_{t-1} + \\ & b_1 \Delta(E_t + P^{*1}_{y_t} - P_{y_t}) + \ldots + b_k \Delta(E_t + P^{*k}_{y_t} - P_{y_t}) + \\ & c_1 \Delta Y^{*1}_t + \ldots + c_k \Delta Y^{*k}_t + \\ & a_7 \mathrm{DUM7475} + a_8 \mathrm{DUM7576} + a_9 \mathrm{time} \end{aligned} \tag{4}$$

For each variable with an asterisk, indicating foreign countries, a foreign country denoted in Table 2 may appear in the equation. For Belgium, e.g., the general equation implies $k = 3$ because there are three countries of interest: Germany, France and the Netherlands. As level variables we, finally, included three (domestic) variables, $Y_{t-1}, G_{t-1}, RL_{t-1} - \Delta P_{y_t}$, assuming a long run relationship between them. Note, that for convenience sake, we do not consider a forward looking term like $\Delta(RL_t - \Delta P_{y_{t+1}})$ [3]. We included step dummies in the general equation: DUM7475 is defined as one for the years 1960-1973 and zero for the years 1974-1991 and DUM7576 is defined accordingly. These dummies belong to the long run relationship of the general equation and are introduced to capture the oil price shock during the 1973-1974 period. In Perron [22] it is shown that this oil shock had persistent negative effects on domestic GDP growth of oil importing countries. Furthermore, a time dummy is introduced to capture accelerated exogenous growth effects of domestic demand [4]. We expect the sign of $a_2, a_4, a_7, a_8, a_9, b_1, \ldots, b_k, c_1, \ldots, c_k \geq 0$, and $a_1, a_3 \leq 0$.

The estimation results are presented in Table 3. As can be seen from our results, the level variables $Y_{-1}, G_{-1}, rl_{-1} (= RL_{-1} - \Delta P_y)$ showed significant results in most cases, except in the case of Ireland where G_{-1} did not have an impact according to our supposed theory and, therefore, was excluded. In the case of Japan we could not find any significant impact of the real interest rate. Difference variables of government expenditure appeared in all equations, except Japan and Denmark. In the case of France, Italy and the United Kingdom, the significance of this variable is rather low. Direct linkages are modelled in each equation; however, not all the countries, indicated in Table 2, yielded significant results. As expected, Germany has a (direct) impact on all other countries except on Ireland. Two countries with considerable influence are also France and the USA; these two countries have direct linkages with five other countries. Especially the impact of GDP growth of France is strong in the equations of Belgium, Germany and the United Kingdom. Real exchange rates effects are largest in the countries Belgium, France and the Netherlands and absent in Denmark, the USA and Japan. A component of foreign growth was found in every country. Large foreign growth effects were found in Belgium, Germany, Denmark, United Kingdom and the Netherlands. In five countries one dummy, capturing the oil shock, had a significant impact and for eight countries the dummy time, indicating exogenous growth, had a significant impact.

3.2 The GDP price inflation

Starting from the equilibrium specification in Table 1, we specified ECM-dynamics as indicated in the introduction of this section. It should be stressed that the lagged level component $(Y_{-1} - \bar{Y}_{-1})$,

[3] In general, the inclusion of this term would not alter the estimation results very much.

[4] Fairly speaking, this time variable should be included in the long run relationship where it can be interpreted as an exogonous growth component.

Table 3: Estimation results of the aggregate demand equation[a]

Belgium:

$$\Delta Y^{Be} = \underset{(3.45)}{-8.94} - \underset{(0.15)}{0.34}Y^{Be}_{-1} + \underset{(0.06)}{0.14}G^{Be}_{-1} - \underset{(0.16)}{0.38}rl^{Be}_{-1} + \underset{(0.15)}{0.29}\Delta G^{Be} + \underset{(0.17)}{0.17}\Delta rl^{Be}_{-1} + \underset{(0.08)}{0.17}\Delta\lambda^{BeNl}$$
$$\underset{(0.15)}{0.13}\Delta Y^{Ge} + \underset{(0.23)}{0.47}\Delta Y^{Fr} + \underset{(0.18)}{0.40}\Delta Y^{Nl} + \underset{(0.01)}{0.026}\ \mathrm{DUM7576} + \underset{(0.002)}{0.006}\,time$$

$\overline{R}^2 = 0.80$, $SE = 0.09$, $t(\hat{\rho}) = -0.97$

Germany:

$$\Delta Y^{Ge} = \underset{(2.16)}{-6.30} - \underset{(0.14)}{0.37}Y^{Ge}_{-1} + \underset{(0.08)}{0.22}G^{Ge}_{-1} - \underset{(0.21)}{0.33}rl^{Ge}_{-1} + \underset{(0.10)}{0.51}\Delta G^{Ge} - \underset{(0.19)}{0.42}\Delta rl^{Ge}_{-1} + \underset{(0.10)}{0.26}\Delta Y^{Us}$$
$$+\underset{(0.19)}{0.52}\Delta Y^{Fr} + \underset{(0.12)}{0.09}\Delta Y^{Ja} + \underset{(0.02)}{0.03}\Delta\lambda^{GeUs} + \underset{(0.015)}{0.031}\ \mathrm{DUM7475} + \underset{(0.002)}{0.004}\,time$$

$\overline{R}^2 = 0.82$, $SE = 0.08$, $t(\hat{\rho}) = -0.32$

France:

$$\Delta Y^{Fr} = \underset{(2.53)}{-5.16} - \underset{(0.06)}{0.11}Y^{Fr}_{-1} + \underset{(0.06)}{0.03}G^{Fr}_{-1} - \underset{(0.14)}{0.33}rl^{Fr}_{-1} + \underset{(0.14)}{0.12}\Delta G^{Fr} + \underset{(0.11)}{0.28}\Delta Y^{Uk} + \underset{(0.10)}{0.16}\Delta Y^{Ge}$$
$$+\underset{(0.04)}{0.10}\Delta\lambda^{FrGe} + \underset{(0.03)}{0.06}\Delta\lambda^{FrUk} + \underset{(0.010)}{0.023}\ \mathrm{DUM7475} + \underset{(0.002)}{0.003}\,time$$

$\overline{R}^2 = 0.82$, $SE = 0.06$, $t(\hat{\rho}) = -0.73$

Denmark:

$$\Delta Y^{Dn} = \underset{(2.22)}{-2.39} - \underset{(0.10)}{0.43}Y^{Dn}_{-1} + \underset{(0.04)}{0.14}G^{Dn}_{-1} - \underset{(0.11)}{0.13}rl^{Dn}_{-1} + \underset{(0.12)}{0.46}\Delta Y^{Ge} + \underset{(0.11)}{0.28}\Delta Y^{Uk}$$
$$+\underset{(0.001)}{0.003}\ time$$

$\overline{R}^2 = 0.82$, $SE = 0.12$, $t(\hat{\rho}) = -0.80$

United Kingdom:

$$\Delta Y^{Uk} = \underset{(5.61)}{-12.6} - \underset{(0.13)}{0.32}Y^{Uk}_{-1} + \underset{(0.05)}{0.04}G^{Uk}_{-1} - \underset{(0.13)}{0.17}rs^{Uk}_{-1} + \underset{(0.07)}{0.05}\Delta G^{Uk} - \underset{(0.08)}{0.08}\Delta rs^{Uk}_{-1} + \underset{(0.04)}{0.09}\Delta\lambda^{UkGe}$$
$$+\underset{(0.24)}{0.61}\Delta Y^{Fr} + \underset{(0.36)}{0.36}\Delta Y^{Us} + \underset{(0.02)}{0.02}\ \mathrm{DUM7475} + \underset{(0.004)}{0.008}\,time$$

$\overline{R}^2 = 0.68$, $SE = 0.15$, $t(\hat{\rho}) = -0.34$

Ireland:

$$\Delta Y^{Ir} = \underset{(11.8)}{-48.9} - \underset{(0.16)}{0.66}Y^{Ir}_{-1} - \underset{(0.13)}{0.38}rs^{Ir}_{-1} + \underset{(0.10)}{0.21}\Delta G^{Ir} + \underset{(0.11)}{0.15}\Delta rs^{Ir}_{-1} + \underset{(0.18)}{0.43}\Delta Y^{Ir}_{-1} + \underset{(0.21)}{0.22}\Delta Y^{Us}$$
$$+\underset{(0.04)}{0.03}\Delta\lambda^{IrUs} + \underset{(0.07)}{0.07}\Delta\lambda^{IrUk} + \underset{(0.007)}{0.028}\ time$$

$\overline{R}^2 = 0.35$, $SE = 0.32$, $t(\hat{\rho}) = 0.35$

Italy:

$$\Delta Y^{It} = \underset{(0.49)}{0.64} - \underset{(0.08)}{0.11}Y^{It}_{-1} + \underset{(0.05)}{0.06}G^{It}_{-1} + \underset{(0.08)}{0.07}\Delta G^{It} - \underset{(0.08)}{0.45}\Delta rl^{It}_{-1} + \underset{(0.22)}{0.34}\Delta Y^{Fr} + \underset{(0.11)}{0.06}\Delta Y^{Us}$$
$$+\underset{(0.02)}{0.02}\Delta\lambda^{ItUs} + \underset{(0.07)}{0.07}\Delta\lambda^{GeIt}$$

$\overline{R}^2 = 0.46$, $SE = 0.27$, $t(\hat{\rho}) = 0.59$

Netherlands:

$$\Delta Y^{Nl} = \underset{(2.41)}{-3.00} - \underset{(0.11)}{0.20}Y^{Nl}_{-1} + \underset{(0.06)}{0.10}G^{Nl}_{-1} - \underset{(0.24)}{0.31}rl^{Nl} + \underset{(0.13)}{0.35}\Delta G^{Nl} + \underset{(0.13)}{0.25}\Delta rl^{Nl}_{-1} + \underset{(0.13)}{0.25}\Delta Y^{Ge}$$
$$+\underset{(0.26)}{0.27}\Delta Y^{Fr} + \underset{(0.18)}{0.46}\Delta Y^{Be} + \underset{(0.07)}{0.21}\Delta\lambda^{NlBe} + \underset{(0.12)}{0.13}\Delta\lambda^{NlGe} + \underset{(0.02)}{0.02}\Delta\lambda^{NlUs} + \underset{(0.002)}{0.002}\ time$$

$\overline{R}^2 = 0.83$, $SE = 0.08$, $t(\hat{\rho}) = -0.57$

USA:

$$\Delta Y^{Us} = \underset{(5.11)}{-7.36} - \underset{(0.18)}{0.50}Y^{Us}_{-1} + \underset{(0.12)}{0.21}G^{Us}_{-1} - \underset{(0.21)}{0.26}rs^{Us}_{-1} + \underset{(0.23)}{0.31}\Delta G^{Us} - \underset{(0.24)}{0.38}\Delta rs^{Us}_{-1} + \underset{(0.15)}{0.39}\Delta Y^{Us}_{-1}$$
$$+\underset{(0.17)}{0.33}\Delta Y^{Ge} + \underset{(0.003)}{0.006}\ time$$

$\overline{R}^2 = 0.64$, $SE = 0.19$, $t(\hat{\rho}) = 2.03$

Japan:

$$\Delta Y^{Ja} = \underset{(0.22)}{0.52} - \underset{(0.05)}{0.12}Y^{Ja}_{-1} + \underset{(0.04)}{0.09}G^{Ja}_{-1} + \underset{(0.17)}{0.42}\Delta Y^{Ge} + \underset{(0.02)}{0.06}\ \mathrm{DUM7475}$$

$\overline{R}^2 = 0.73$, $SE = 0.29$, $t(\hat{\rho}) = 0.79$

a. *The real echange rate between two countries, e.g., Belgium and the Netherlands in the first equation, λ^{BeNl}, is defined as $E + P^{Nl} - P^{Be}$, where E is the exchange rate between Belgium and the Netherlands, defined as the amount of Belgian Francs for one Dutch Guilder. The real long term interest rate is defined as $rl_{-1} := RL_{-1} - \Delta P_y$ and the real short term interest rate as $rs_{-1} := RS_{-1} - \Delta P_y$.*

being specified as the demand pull inflation component in Table 1, had no significant impact in the estimation results and, therefore, will not be considered as level variable in the equilibrium specification of the following general equation:

$$\begin{aligned}\Delta P_{y_t} = \quad & a_0 + a_1 P_{y_{t-1}} + a_2 W_{t-1} + \\ & a_3 \Delta P_{y_{t-1}} + a_4 \Delta W_t + a_5 \Delta W_{t-1} + a_6 \Delta(Y - \bar{Y})_t + a_7 \Delta(Y - \bar{Y})_{t-1} + \\ & b_1 \Delta(E + P_y^{*1})_t + \ldots + b_k \Delta(E + P_y^{*k})_t + \\ & c_1 \Delta(E + P_y^{*1})_{t-1} + \ldots + c_k \Delta(E + P_y^{*k})_{t-1} \end{aligned} \quad (5)$$

For estimating equation (5) we followed the same procedure as defined in the previous aggregate demand subsection. Our decision criterium was that all parameteres $a_2, a_4, b_1, \ldots, b_k, c_1, \ldots c_k$ should be nonnegative and a_1 should be negative. The signs of a_6 and a_7 are ambiguous, where a positive sign indicates a demand effect and a negative sign a supply effect. This procedure worked quite well for all the ten countries. The results can be found in Table 4. We have to make some additional remarks. The long run impact of the level of wages to GDP-prices was restricted to one in Italy. The simulation results improved considerably when imposing this restriction. Furthermore, a first difference wage effect, which was significant in the original OLS-regression but not in the 3SLS-estimation, was excluded in the USA and in the United Kingdom. In the case of the GDP-price equation of the United Kingdom, the impact of the GDP-price of the year 1975 worked as a lever. Therefore we included a dummy DUM75, which is one in 1975 and zero elsewhere, into the equation.

The multipliers of differences in short run per capita wage costs (ΔW) are in the same range (0-0.67) as published in the Quest model[3]. However, there are some differences among countries, which can be explained, not only by the different data samples, but also by the different sets of variables which were taken into account during the estimation process. In our case, we included foreign variables in the estimation process and this had a serious effect in almost every country as can be seen from the results. As expected small countries, such as Belgium, the Netherlands and Ireland have strong foreign price effects. In the Netherlands we see the remarkable fact that the lagged (home) inflation variable disappeared but, instead, two foreign inflation variables were included. The appearence of these foreign variables indicate a high degree of openness for the economy in the Netherlands. We see that the USA have a strong impact on other countries. Its competitive GDP inflation level had substantial effects in four of the eight EU-countries. The variable $\Delta(Y - \bar{Y})$ had serious effects in all the countries. In general, excluding Italy and France, the variable had a positive lagged effect and a negative current effect, indicating a cyclical price behaviour. A rise in output instantanously lowers prices, and raises prices one year later. Note, that the sign of the overall effect of a change in output from trend is unclear.

3.3 The consumer price inflation

The equation for the consumer price inflation was estimated in the same way as the GDP price inflation. We used the equilibrium equation from Table 1 and we made a dynamic formulation of it as explained in the introduction of this section. A long run relationship in each country was assumed between the consumer price level P_c and the output price level P_y. The general equation is specified as follows:

$$\begin{aligned}\Delta P_{c_t} = \quad & a_0 + a_1 P_{c_{t-1}} + a_2 P_{y_{t-1}} + \\ & a_3 \Delta P_{y_t} + a_4 \Delta P_{y_{t-1}} + a_5 \Delta P_{c_{t-1}} + \\ & b_1 \Delta(E + P_{y_t}^{*1}) + \ldots + b_k \Delta(E + P_{y_t}^{*k}) + \\ & c_1 \Delta(E + P_{y_{t-1}}^{*1}) + \ldots + b_k \Delta(E + P_{y_{t-1}}^{*k}) \end{aligned} \quad (6)$$

The estimation results, after applying the general to specific estimation scheme, can be found in Table 5. Our prior belief was that all parameters should be nonnegative, except a_1 which should

Table 4: Estimation results for the GDP-price equation

Belgium:

$$\Delta P_y^{Be} = -0.36 + 0.31\Delta P_{y_{-1}}^{Be} + 0.29\Delta W^{Be} + 0.32\Delta(Y-\bar{Y})_{-1}^{Be} + 0.18\Delta P^{BeNl}$$

(0.62) (0.13) (0.11) (0.13) (0.07)

$$-0.036 P_{y_{-1}}^{Be} + 0.026 W_{-1}^{Be}$$

(0.075) (0.044)

$\overline{R}^2 = 0.82$, $SE = 0.11$, $t(\hat{\rho}) = 1.48$

Germany:

$$\Delta P_y^{Ge} = -0.28 + 0.27\Delta P_{y_{-1}}^{Ge} + 0.45\Delta W^{Ge} - 0.18\Delta(Y-\bar{Y})^{Ge} + 0.15\Delta(Y-\bar{Y})_{-1}^{Ge}$$

(0.28) (0.10) (0.08) (0.08) (0.07)

$$+0.014\Delta P_{-1}^{GeUs} - 0.028 P_{y_{-1}}^{Ge} + 0.026 W_{-1}^{Ge}$$

(0.011) (0.045) (0.044)

$\overline{R}^2 = 0.87$, $SE = 0.03$, $t(\hat{\rho}) = -1.07$

France:

$$\Delta P_y^{Fr} = -0.66 + 0.29\Delta P_{y_{-1}}^{Fr} + 0.57\Delta W^{Fr} - 0.13\Delta(Y-\bar{Y})_{-1}^{Fr} + 0.02\Delta P_{-1}^{FrUs}$$

(0.36) (0.07) (0.06) (0.10) (0.01)

$$-0.037 P_{y_{-1}}^{Fr} + 0.035 W_{-1}^{Fr}$$

(0.027) (0.019)

$\overline{R}^2 = 0.97$, $SE = 0.03$, $t(\hat{\rho}) = -0.29$

Denmark:

$$\Delta P_y^{Dn} = -1.22 + 0.33\Delta P_{y_{-1}}^{Dn} + 0.39\Delta W^{Dn} - 0.25\Delta(Y-\bar{Y})^{Dn} + 0.16\Delta(Y-\bar{Y})_{-1}^{Dn}$$

(0.55) (0.14) (0.11) (0.08) (0.09)

$$+0.03\Delta P_{-1}^{DnUk} + 0.02\Delta P_{-1}^{DnUs} - 0.126 P_{y_{-1}}^{Dn} + 0.101 W_{-1}^{Dn}$$

(0.03) (0.02) (0.057) (0.044)

$\overline{R}^2 = 0.88$, $SE = 0.08$, $t(\hat{\rho}) = -0.03$

United Kingdom:

$$\Delta P_y^{Uk} = -0.80 + 0.71\Delta P_{y_{-1}}^{Uk} - 0.56\Delta(Y-\bar{Y})^{Uk} + 0.99\Delta(Y-\bar{Y})_{-1}^{Uk}$$

(0.64) (0.09) (0.16) (0.23)

$$+0.14\mathrm{DUM75} - 0.11 P_{y_{-1}}^{Uk} + 0.08 W_{-1}^{Uk}$$

(0.02) (0.08) (0.08)

$\overline{R}^2 = 0.89$, $SE = 0.26$, $t(\hat{\rho}) = 0.18$

Ireland:

$$\Delta P_y^{Ir} = -0.44 + 0.67\Delta W^{Ir} - 0.43\Delta(Y-\bar{Y})^{Ir} + 0.25\Delta P_{-1}^{IrUk}$$

(0.69) (0.11) (0.16) (0.06)

$$-0.058 P_{y_{-1}}^{Ir} + 0.044 W_{-1}^{Ir}$$

(0.098) (0.072)

$\overline{R}^2 = 0.89$, $SE = 0.33$, $t(\hat{\rho}) = -0.38$

Italy:

$$\Delta P_y^{It} = -0.13 + 0.40\Delta P_{y_{-1}}^{It} + 0.55\Delta W^{It} + 0.22\Delta(Y-\bar{Y})^{It} + 0.06\Delta P^{ItGe}$$

(0.03) (0.08) (0.08) (0.12) (0.05)

$$-0.035(P_{y_{-1}}^{It} - W_{-1}^{It})$$

(0.011)

$\overline{R}^2 = 0.95$, $SE = 0.13$, $t(\hat{\rho}) = -0.19$

Netherlands:

$$\Delta P_y^{Nl} = -0.56 + 0.57\Delta W^{Nl} - 0.17\Delta(Y-\bar{Y})^{Nl} + 0.18\Delta P_{-1}^{NlBe} + 0.07\Delta P^{NlUs}$$

(0.37) (0.07) (0.08) (0.06) (0.02)

$$-0.064 P_{y_{-1}}^{Nl} + 0.051 W_{-1}^{Nl}$$

(0.054) (0.051)

$\overline{R}^2 = 0.94$, $SE = 0.05$, $t(\hat{\rho}) = -0.20$

USA:

$$\Delta P_y^{Us} = -3.72 + 0.71\Delta P_{y_{-1}}^{Us} + 0.11\Delta(Y-\bar{Y})_{-1}^{Us} - 0.24 P_{y_{-1}}^{Us} + 0.22 W_{-1}^{Us}$$

(1.30) (0.12) (0.10) (0.08) (0.08)

$\overline{R}^2 = 0.80$, $SE = 0.10$, $t(\hat{\rho}) = 0.58$

Japan:

$$\Delta P_y^{Ja} = -1.51 + 0.57\Delta P_{y_{-1}}^{Ja} + 0.74\Delta W^{Ja} - 0.54\Delta W^{Ja} - 0.30\Delta(Y-\bar{Y})^{Ja} +$$

(0.82) (0.16) (0.13) (0.16) (0.18)

$$0.14\Delta(Y-\bar{Y})_{-1}^{Ja} - 0.17 P_{y_{-1}}^{Ja} + 0.10 W_{-1}^{Ja}$$

(0.14) (0.10) (0.05)

$\overline{R}^2 = 0.83$, $SE = 0.22$, $t(\hat{\rho}) = -1.21$

a. *The competetive GDP price between a home and a foreign country, e.g., Belgium and the Netherlands in the first equation,* P^{BeNl}, *is defined as* $E + P_y^{Nl}$, *where* E *is the exchange rate between Belgium and the Netherlands, defined as the amount of Belgian Francs for one Dutch Guilder.*

be negative. We have to remark that the error correction term (indicated by the lagged level variables) was excluded for Belgium, Ireland, Italy, Netherlands and USA, since the significance of these terms was very low and the simulation results turned out to be better without these terms. However, consumer price levels and output price levels are still very strongly related with each other in all countries. The reason for this is that the most important indicator for the consumer price inflation is the GDP price inflator. If we look at the home effects indicated by $\Delta P_{y_t}, \Delta P_{y_{t-1}}$ and $\Delta P_{c_{t-1}}$ then we see that in almost all cases these variables explain more than 80 % of the consumer price inflation. We see that Germany had a significant effect in all countries, except in France and Denmark. If we consider the multipliers of the foreign effects, we see that small countries like Belgium, Denmark, Ireland and the Netherlands are mostly influenced by foreign countries. This is not astonishing because it is well known that these economies are the most open ones of all the EU-countries. [5]. The long run elasticity, of the long run relationship between the consumer price and the GDP-price, equals almost one in those cases where it had a significant impact.

3.4 The employment equation

For the general specification of total employment in the individual economies we followed the scheme which includes all home level variables of the equilibrium equation, as specified in Table 1, and all present and past changes of all the variables. Furthermore, we included a time dummy which represents an autonomous (technology) trend. The general equation is specified as follows:

$$\begin{aligned}\Delta N_t = \quad & a_0 + a_1 N_{t-1} + a_2(W - P_y)_{t-1} + a_3 Y_{t-1} \\ & + a_4 \Delta N_{t-1} + a_5 \Delta(W_t - P_{y_t}) + a_6 \Delta(W_{t-1} - P_{y_{t-1}}) + \\ & a_7 \Delta Y_t + a_8 \Delta Y_{t-1} + a_9 \text{time} + \\ & b_1 \Delta(E_t + P_{y_t}^{*1} - P_{y_t}) + \ldots + b_k \Delta(E_t + P_{y_t}^{*k} - P_{y_t}) + \\ & c_1 \Delta(E_{t-1} + P_{y_{t-1}}^{*1} - P_{y_{t-1}}) + \ldots + c_k \Delta(E_{t-1} + P_{y_{t-1}}^{*k} - P_{y_{t-1}}) \qquad (7)\end{aligned}$$

According to economic theory our priors were that $a_1, a_2, a_5 \leq 0$ and $a_3, a_7 \geq 0$. The estimation results can be found in Table 6. The error-correction parameter was negative and in absolute value smaller than one in all cases, except for Ireland were it did not occur, indicating a stable relationship. Furthermore, most variables in the error correction term (determined by the level variables $N_{t-1}, W_{r_{t-1}} (:= W_{t-1} - P_{y_{t-1}}), Y_{t-1}$) proved to be significant. However, in some cases the level effect of real wages disappeared. Notice that we did not impose any restriction on the coefficients of the level variables. In general, the estimated coefficient of the level of (lagged) employment is much higher than the estimated coefficient of the level variable of real GDP indicating that in the long run the effect of real GDP on employment is relatively small. In the equation of the United Kingdom, and to a lesser extent France, we found a significant negative time effect, indicating that technical progress suppresses activity on the labour market. A lagged effect of changes in total employment can be observed in all the equations, except the equations for France, Italy, USA and Japan. This process is remarkably strong in the Netherlands where the coefficient of ΔN_{t-1} is 0.61. The impact of the change in real wages on employment is negative as expected; however, a positive lagged effect was found in France and Italy. The output elasticity on employment is significant (and positive) in each country. Remark that the overall effect of the change in output is rather strong and ranges from 0.29 till 0.53 in the EU-economies. The impact of foreign prices is ambiguous. We found a strong foreign impact in France and Ireland. In Italy we included a dummy, DUM65, which is explained in Appendix A.

[5] For measures of openness, see, e.g., the Quest model [3]

Table 5: Estimation results for the consumer price equation[a]

Belgium:			
$\Delta P_c^{Be} = -0.008 + 0.81\Delta P_y^{Be} + 0.07\Delta P_{-1}^{BeGe} + 0.13\Delta P^{BeFr} + 0.12\Delta P_{-1}^{BeFr}$	$\overline{R}^2$	=	0.87
(0.004) (0.09) (0.05) (0.05) (0.05)	SE	=	0.10
	$t(\hat{\rho})$	=	-0.35
Germany:			
$\Delta P_c^{Ge} = 0.007 + 0.40\Delta P_y^{Ge} + 0.32\Delta P_{c_{-1}}^{Ge} + 0.03\Delta P^{GeFr} + 0.06\Delta P^{GeUs}$	$\overline{R}^2$	=	0.91
(0.004) (0.10) (0.08) (0.01) (0.01)	SE	=	0.03
$-0.24P_{c_{-1}}^{Ge} + 0.22P_{y_{-1}}^{Ge}$	$t(\hat{\rho})$	=	1.32
(0.05) (0.05)			
France:			
$\Delta P_c^{Fr} = 0.00 + 0.94\Delta P_y^{Fr} + 0.03\Delta P^{FrUk} + 0.04\Delta P^{FrUs}$	$\overline{R}^2$	=	0.96
(0.00) (0.05) (0.02) (0.01)	SE	=	0.04
$-0.37P_{c_{-1}}^{Fr} + 0.37P_{y_{-1}}^{Fr}$	$t(\hat{\rho})$	=	-0.32
(0.12) (0.13)			
Denmark:			
$\Delta P_c^{Dn} = -0.00 + 0.81\Delta P_y^{Dn} + 0.15\Delta P_{y_{-1}}^{Dn} + 0.06\Delta P^{DnUk}$	$\overline{R}^2$	=	0.85
(0.01) (0.14) (0.14) (0.03)	SE	=	0.13
$-0.18P_{c_{-1}}^{Fr} + 0.18P_{y_{-1}}^{Fr}$	$t(\hat{\rho})$	=	-0.32
(0.09) (0.09)			
United Kingdom:			
$\Delta P_c^{Uk} = 0.00 + 0.89\Delta P_y^{Uk} + 0.02\Delta P^{UkGe} + 0.07\Delta P_{-1}^{UkFr} + 0.03\Delta P^{UkUs}$	$\overline{R}^2$	=	0.98
(0.00) (0.03) (0.02) (0.02) (0.02)	SE	=	0.05
$-0.47P_{c_{-1}}^{Uk} + 0.45P_{y_{-1}}^{Uk}$	$t(\hat{\rho})$	=	-1.37
(0.09) (0.09)			
Ireland:			
$\Delta P_c^{Ir} = -0.004 + 0.43\Delta P_y^{Ir} + 0.13\Delta P_{y_{-1}}^{Ir} + 0.09\Delta P^{IrGe} + 0.33\Delta P^{IrUk}$	$\overline{R}^2$	=	0.92
(0.006) (0.11) (0.09) (0.07) (0.07)	SE	=	0.26
$+0.07\Delta P_{-1}^{IrUs}$	$t(\hat{\rho})$	=	0.15
(0.04)			
Italy:			
$\Delta P_c^{It} = -0.006 + 0.91\Delta P_y^{It} + 0.04\Delta P_{-1}^{ItGe} + 0.04\Delta P^{ItFr} + 0.03\Delta P^{ItUs}$	$\overline{R}^2$	=	0.98
(0.003) (0.06) (0.03) (0.03) (0.02)	SE	=	0.05
	$t(\hat{\rho})$	=	0.40
Netherlands:			
$\Delta P_c^{Nl} = -0.008 + 0.86\Delta P_y^{Nl} + 0.10\Delta P_{-1}^{NlGe} + 0.04\Delta P^{NlUk} + 0.10\Delta P_{-1}^{NlFr}$	$\overline{R}^2$	=	0.92
(0.004) (0.07) (0.08) (0.02) (0.04)	SE	=	0.08
	$t(\hat{\rho})$	=	1.06
USA:			
$\Delta P_c^{Us} = 0.000 + 0.94\Delta P_y^{Us} + 0.02\Delta P_{-1}^{UsGe}$	$\overline{R}^2$	=	0.92
(0.000) (0.05) (0.01)	SE	=	0.04
	$t(\hat{\rho})$	=	0.32
Japan:			
$\Delta P_c^{Ja} = 0.00 + 0.78\Delta P_y^{Ja} + 0.13\Delta P_{y_{-1}}^{Ja} + 0.05\Delta P^{JaUs} + 0.04\Delta P_{-1}^{JaGe}$	$\overline{R}^2$	=	0.95
(0.00) (0.07) (0.08) (0.02) (0.02)	SE	=	0.08
$-0.20P_{c_{-1}}^{Ja} + 0.22P_{y_{-1}}^{Ja}$	$t(\hat{\rho})$	=	-0.57
(0.15) (0.17)			

a. *The import price between a home and a foreign country, e.g. Belgium and Germany in the first equation,* P^{BeGe}*, is defined as* $E + P_y^{Ge}$*, where* E *is the exchange rate between Belgium and Germany, defined as the amount of Belgian Francs for one Deutschmark.*

Table 6: Estimation results of the employment equation[a]

Belgium:

$$\Delta N^{Be} = \underset{(0.47)}{1.73} + \underset{(0.15)}{0.15}\Delta N^{Be}_{-1} + \underset{(0.06)}{0.35}\Delta Y^{Be} + \underset{(0.07)}{0.18}\Delta Y^{Be}_{-1} - \underset{(0.03)}{0.05}\Delta\lambda^{BeGe} - \underset{(0.06)}{0.26}N^{Be}_{-1} + \underset{(0.01)}{0.02}Y^{Be}_{-1}$$

$\overline{R}^2 = 0.67$, $SE = 0.03$, $t(\hat{\rho}) = -1.56$

Germany:

$$\Delta N^{Ge} = \underset{(0.90)}{1.85} + \underset{(0.10)}{0.55}\Delta N^{Ge}_{-1} - \underset{(0.09)}{0.15}\Delta Wr^{Ge} + \underset{(0.07)}{0.49}\Delta Y^{Ge} - \underset{(0.11)}{0.25}N^{Ge}_{-1} - \underset{(0.07)}{0.08}Wr^{Ge}_{-1} + \underset{(0.07)}{0.11}Y^{Ge}_{-1}$$

$\overline{R}^2 = 0.85$, $SE = 0.03$, $t(\hat{\rho}) = -1.98$

France:

$$\Delta N^{Fr} = \underset{(1.24)}{2.56} - \underset{(0.07)}{0.15}\Delta Wr^{Fr} + \underset{(0.06)}{0.12}\Delta Wr^{Fr}_{-1} + \underset{(0.05)}{0.31}\Delta Y^{Fr} + \underset{(0.06)}{0.20}\Delta Y^{Fr}_{-1} - \underset{(0.01)}{0.04}\Delta\lambda^{FrGe}_{-1} - \underset{(0.10)}{0.16}N^{Fr}_{-1} - \underset{(0.03)}{0.03}Wr^{Fr}_{-1} + \underset{(0.03)}{0.09}Y^{Fr}_{-1} - \underset{(0.000)}{0.001}time$$

$\overline{R}^2 = 0.88$, $SE = 0.01$, $t(\hat{\rho}) = -0.59$

Denmark:

$$\Delta N^{Dn} = \underset{(0.84)}{3.08} + \underset{(0.11)}{0.39}\Delta N^{Dn}_{-1} - \underset{(0.09)}{0.20}\Delta Wr^{Dn} + \underset{(0.06)}{0.39}\Delta Y^{Dn} - \underset{(0.01)}{0.02}\Delta\lambda^{DnUs}_{-1} - \underset{(0.15)}{0.58}N^{Dn}_{-1} - \underset{(0.06)}{0.14}Wr^{Dn}_{-1} + \underset{(0.08)}{0.24}Y^{Dn}_{-1}$$

$\overline{R}^2 = 0.76$, $SE = 0.04$, $t(\hat{\rho}) = -2.40$

United Kingdom:

$$\Delta N^{Uk} = \underset{(2.46)}{9.81} + \underset{(0.12)}{0.53}\Delta N^{Uk}_{-1} - \underset{(0.11)}{0.32}\Delta Wr^{Uk} + \underset{(0.09)}{0.46}\Delta Y^{Uk} + \underset{(0.04)}{0.05}\Delta\lambda^{UkFr} - \underset{(0.03)}{0.03}\Delta\lambda^{UkGe}_{-1} - \underset{(0.09)}{0.40}N^{Uk}_{-1} - \underset{(0.07)}{0.17}Wr^{Uk}_{-1} + \underset{(0.11)}{0.39}Y^{Uk}_{-1} - \underset{(0.001)}{0.005}time$$

$\overline{R}^2 = 0.81$, $SE = 0.05$, $t(\hat{\rho}) = -0.27$

Ireland:

$$\Delta N^{Ir} = \underset{(0.00)}{-0.01} + \underset{(0.14)}{0.31}\Delta N^{Ir}_{-1} - \underset{(0.07)}{0.19}\Delta Wr^{Ir}_{-1} + \underset{(0.07)}{0.28}\Delta Y^{Ir} + \underset{(0.09)}{0.11}\Delta Y^{Ir}_{-1} - \underset{(0.02)}{0.07}\Delta\lambda^{IrUs} + \underset{(0.03)}{0.03}\Delta\lambda^{IrUk}_{-1}$$

$\overline{R}^2 = 0.60$, $SE = 0.07$, $t(\hat{\rho}) = -1.77$

Italy:

$$\Delta N^{It} = \underset{(0.54)}{0.57} + \underset{(0.07)}{0.09}\Delta Wr^{It}_{-1} + \underset{(0.07)}{0.15}\Delta Y^{It} + \underset{(0.06)}{0.14}\Delta Y^{It}_{-1} - \underset{(0.06)}{0.12}N^{It}_{-1} + \underset{(0.01)}{0.04}Y^{Ir}_{-1} + \underset{(0.01)}{0.02}\mathrm{DUM65}$$

$\overline{R}^2 = 0.54$, $SE = 0.04$, $t(\hat{\rho}) = 0.23$

Netherlands:

$$\Delta N^{Nl} = \underset{(0.29)}{1.61} + \underset{(0.10)}{0.61}\Delta N^{Nl}_{-1} + \underset{(0.05)}{0.34}\Delta Y^{Nl} + \underset{(0.05)}{0.10}\Delta Y^{Nl}_{-1} - \underset{(0.04)}{0.26}N^{Nl}_{-1} - \underset{(0.03)}{0.03}Wr^{Nl}_{-1} + \underset{(0.02)}{0.08}Y^{Nl}_{-1}$$

$\overline{R}^2 = 0.88$, $SE = 0.02$, $t(\hat{\rho}) = -2.26$

USA:

$$\Delta N^{Us} = \underset{(0.09)}{-0.10} - \underset{(0.16)}{0.11}\Delta Wr^{Us} + \underset{(0.06)}{0.52}\Delta Y^{Us} + \underset{(0.06)}{0.12}\Delta Y^{Us}_{-1} + \underset{(0.01)}{0.02}\Delta\lambda^{UsJp}_{-1} - \underset{(0.05)}{0.18}N^{Us}_{-1} + \underset{(0.04)}{0.14}Y^{Us}_{-1}$$

$\overline{R}^2 = 0.81$, $SE = 0.04$, $t(\hat{\rho}) = -0.40$

Japan:

$$\Delta N^{Ja} = \underset{(0.72)}{0.86} - \underset{(0.06)}{0.19}Wr^{Jp} + \underset{(0.06)}{0.20}\Delta Y^{Ja} - \underset{(0.08)}{0.08}N^{Ja}_{-1} - \underset{(0.02)}{0.05}Wr^{Ja}_{-1} + \underset{(0.02)}{0.04}Y^{Ja}_{-1}$$

$\overline{R}^2 = 0.38$, $SE = 0.03$, $t(\hat{\rho}) = -0.01$

a. *Real wages, $(W - P_y)$, are presented as Wr in this table. λ, e.g. λ^{BeGe} in the first equation, is defined in the same way as in Table 5.*

3.5 The nominal wage equation per private sector employee

It is well-known in macroeconometric modelling that the wage equation is one of the key equations in the model. Usually this equation is adjusted when simulation results are not satisfactory. First of all, we excluded the (lagged) terms of trade , $P_c - P_y$ since the inclusion of these terms yielded a bad simulation performance (see, e.g., the Quest model [3, page 198], for the same findings: "Another problem may arise in the case of any lasting discrepancy between production and consumption prices. The terms-of-trade coefficient in the wage equation has therefore been set to zero in all countries."). We started with the following general specification of the equation for nominal wages per employee in the private sector:

$$\begin{aligned}\Delta W_t = \; & a_0 + a_1 W_{t-1} + a_2 P_{c_{t-1}} + a_3 (Y-N)_{t-1} + a_4 U_{t-1} + \\ & a_5 \Delta W_{t-1} + a_6 \Delta P_{c_t} + a_7 \Delta P_{c_{t-1}} + a_8 \Delta (Y_t - N_t) + \\ & a_9 \Delta (Y_{t-1} - N_{t-1}) + a_{10} \Delta U_t + a_{11} \Delta U_{t-1}\end{aligned}$$

The selection procedure was based on our priors that $a_1, a_4, a_{10} \leq 0$ and $a_2, a_3, a_6, a_8 \geq 0$. The estimation results can be found in Table 7. We must remark that the specifications listed in this Table are merely equations which were a result of doing static and dynamic simulation exercises and that the general to specific approach was used as a first indication. We included a shock-dummy DUM70 for Germany, which is one in 1970 and zero elsewhere (for an explanation of this dummy we refer to Appendix A). Except for Ireland, where the long run relationship did not prove to be significant, most level variables are included in the equations. In the cases of Germany, France, Italy and Japan we could not find any evidence of a significant negative impact of the unemployment level. The consumer price level did not have any influence in Germany and the USA. The change in labour productivity proved to be an important factor for explaining wages in all countries, except for Italy and to a lesser extent the USA. For seven countries the estimation results of the coefficient of $\Delta(Y - N)$ range from 0.28 till 0.68. Notice, that in the United Kingdom we found a very strong negative impact of a lagged change of labour productivity. Significant effects of lagged growth in wages are observed in all countries except for the United Kingdom, Italy and the USA. The short-run multipliers of consumer price inflation range from 0.48 to 1.04, which is usually considered as satisfactory (see, e.g., Brunia [4] or the Quest model [3]). The error-correction parameter is high for the United Kingdom indicating a low speed of adjustment to its long term-path. Unemployment persistence effects, reflecting the vulnerability of wages to hysteresis, seems only to be present for a small number of countries.

3.6 The long term interest rate

Specifications for the long term interest rates in the various countries appeared to be a difficult task. It is clear that during the sample period and the very short term behaviour of the interest rates there were a lot of institutional changes which made it hard to find a good general equation for the whole sample period. Furthermore, the data concerning the short term interest rate were not very reliable during the sixties. For some countries we had to rely on the discount rate as can be seen in appendix A. Especially the impact of the short term interest rate in this equation is important since the short term interest rate is a policy variable in our model. Viewing these problems we, finally, adopted a very simple approach. As in the Quest model [1] and Brunia [4] we included RL and RS as level variables in our equation. Furthermore, we added growth variables of the long term interest rate of relevant foreign countries, as specified in Table 4. In this way we are sure of the direct international monetary linkages. Furthermore, to ensure the linkage between the real part and the monetary part of the model, consumer price inflation and (in first instance) the growth of the budget deficit were included in the estimation process. This last term did not improve the explanatory power of the equation. Hence, we decided to exclude this term from the

Table 7: Estimation results of the nominal wage equation.

Belgium:

$$\Delta W^{Be} = \underset{(0.57)}{0.26} + \underset{(0.13)}{0.31}\Delta W^{Be}_{-1} + \underset{(0.15)}{0.67}\Delta P^{Be}_{c} + \underset{(0.19)}{0.50}\Delta(Y-N)^{Be} - \underset{(0.07)}{0.13}W^{Be}_{-1} + \underset{(0.08)}{0.21}(Y-N)^{Be}_{-1} + \underset{(0.10)}{0.11}P^{Be}_{c_{-1}} - \underset{(0.19)}{0.25}U^{Be}_{-1}$$

$\overline{R}^2 = 0.87$, $SE = 0.17$, $t(\hat{\rho}) = -1.55$

Germany:

$$\Delta W^{Ge} = \underset{(0.07)}{0.01} + \underset{(0.13)}{0.27}\Delta W^{Ge}_{-1} + \underset{(0.18)}{0.56}\Delta P^{Ge}_{c} + \underset{(0.20)}{0.68}\Delta(Y-N)^{Ge} - \underset{(0.34)}{0.44}\Delta U^{Ge}_{-1} - \underset{(0.04)}{0.06}W^{Ge}_{-1} + \underset{(0.10)}{0.13}(Y-N)^{Ge}_{-1} + \underset{(0.01)}{0.06}\,\mathrm{DUM70}$$

$\overline{R}^2 = 0.85$, $SE = 0.13$, $t(\hat{\rho}) = 0.07$

France:

$$\Delta W^{Fr} = \underset{(1.25)}{3.00} + \underset{(0.10)}{0.36}\Delta W^{Fr}_{-1} + \underset{(0.11)}{0.86}\Delta P^{Fr}_{c} + \underset{(0.28)}{0.28}\Delta(Y-N)^{Fr} - \underset{(0.44)}{0.40}\Delta U^{Fr}_{-1} - \underset{(0.09)}{0.23}W^{Fr}_{-1} + \underset{(0.10)}{0.21}P^{Fr}_{c_{-1}} + \underset{(0.09)}{0.23}(Y-N)^{Fr}_{-1}$$

$\overline{R}^2 = 0.95$, $SE = 0.08$, $t(\hat{\rho}) = -1.21$

Denmark:

$$\Delta W^{Dn} = \underset{(0.70)}{1.77} + \underset{(0.15)}{0.40}\Delta W^{Dn}_{-1} + \underset{(0.16)}{0.81}\Delta P^{Dn}_{c} + \underset{(0.17)}{0.44}\Delta(Y-N)^{Dn} \quad (0.37)$$
$$- \underset{(0.13)}{0.34}W^{Dn}_{-1} + \underset{(0.12)}{0.33}P^{Dn}_{c_{-1}} + \underset{(0.20)}{0.43}(Y-N)^{Dn}_{-1} - \underset{(0.26)}{0.37}U^{Dn}_{-1}$$

$\overline{R}^2 = 0.85$, $SE = 0.17$, $t(\hat{\rho}) = -0.14$

United Kingdom:

$$\Delta W^{Uk} = \underset{(0.82)}{4.23} + \underset{(0.06)}{1.03}\Delta P^{Uk}_{c} + \underset{(0.17)}{0.57}\Delta(Y-N)^{Uk} - \underset{(0.15)}{0.88}\Delta(Y-N)^{Uk}_{-1} - \underset{(0.12)}{0.75}W^{Uk}_{-1} + \underset{(0.13)}{0.73}P^{Uk}_{c_{-1}} + \underset{(0.13)}{0.96}(Y-N)^{Uk}_{-1} - \underset{(0.17)}{0.32}U^{Uk}_{-1}$$

$\overline{R}^2 = 0.95$, $SE = 0.10$, $t(\hat{\rho}) = -0.11$

Ireland:

$$\Delta W^{Ir} = \underset{(0.02)}{0.03} + \underset{(0.19)}{0.05}\Delta W^{Ir}_{-1} + \underset{(0.17)}{0.85}\Delta P^{Ir}_{c} + \underset{(0.25)}{0.39}\Delta(Y-N)^{Ir} - \underset{(0.42)}{0.20}\Delta U^{Ir}_{-1}$$

$\overline{R}^2 = 0.78$, $SE = 0.63$, $t(\hat{\rho}) = 0.91$

Italy:

$$\Delta W^{It} = -\underset{(0.17)}{0.45} + \underset{(0.09)}{1.04}\Delta P^{It}_{c} - \underset{(0.11)}{0.40}W^{It}_{-1} + \underset{(0.11)}{0.37}P^{It}_{c_{-1}} + \underset{(0.12)}{0.46}(Y-N)^{It}_{-1}$$

$\overline{R}^2 = 0.89$, $SE = 0.27$, $t(\hat{\rho}) = -0.70$

Netherlands:

$$\Delta W^{Nl} = \underset{(0.52)}{0.81} + \underset{(0.12)}{0.24}\Delta W^{Nl}_{-1} + \underset{(0.14)}{0.82}\Delta P^{Nl}_{c} + \underset{(0.19)}{0.44}\Delta(Y-N)^{Nl} - \underset{(0.08)}{0.26}W^{Nl}_{-1} + \underset{(0.09)}{0.16}P^{Nl}_{c_{-1}} + \underset{(0.12)}{0.45}(Y-N)^{Nl}_{-1} - \underset{(0.16)}{0.20}U^{Nl}_{-1}$$

$\overline{R}^2 = 0.93$, $SE = 0.15$, $t(\hat{\rho}) = -1.14$

USA:

$$\Delta W^{Us} = \underset{(0.11)}{0.16} + \underset{(0.11)}{0.48}\Delta P^{Us}_{c} + \underset{(0.13)}{0.48}\Delta P^{Us}_{c_{-1}} + \underset{(0.15)}{0.18}\Delta(Y-N)^{Us} - \underset{(0.20)}{0.36}\Delta U^{Us} - \underset{(0.01)}{0.02}W^{Us}_{-1} + \underset{(0.05)}{0.05}(Y-N)^{Us}_{-1} - \underset{(0.15)}{0.06}U^{Us}_{-1}$$

$\overline{R}^2 = 0.88$, $SE = 0.04$, $t(\hat{\rho}) = -1.39$

Japan:

$$\Delta W^{Ja} = \underset{(0.70)}{2.30} + \underset{(0.08)}{0.26}\Delta W^{Ja}_{-1} + \underset{(0.15)}{0.89}\Delta P^{Ja}_{c} + \underset{(0.17)}{0.58}\Delta(Y-N)^{Ja} - \underset{(0.05)}{0.18}W^{Ja}_{-1} + \underset{(0.07)}{0.12}P^{Ja}_{c_{-1}} + \underset{(0.03)}{0.25}(Y-N)^{Ja}_{-1}$$

$\overline{R}^2 = 0.95$, $SE = 0.16$, $t(\hat{\rho}) = -0.35$

general equation. The general equation is specified as follows:

$$\begin{aligned}\Delta RL_t = \quad & a_0 + a_1 RL_{t-1} + a_2 RS_{t-1} + a_3 \Delta P_{c_t} + \\ & a_4 \Delta RL_{t-1} + a_5 \Delta RS_t + a_6 \Delta RS_{t-1} + a_7(\Delta P_{c_t} - \Delta P_{c_{t-1}}) + \\ & b_1 \Delta RL_t^{*1} + ... + b_k \Delta RL_t^{*k}\end{aligned}$$

The estimation results can be found in Table 8. In all the equations the sign of a_1 is, as expected, negative and smaller than one in absolute value, indicating a stable relationship for the ECM-mechanism. For the sample period we found some strong effects concerning the direct linkages. The long term interest rate of the USA seems to be important for Germany and France, whereas all the other European Union countries, except Denmark and Ireland, are linked with Germany and/or France. In the equation of Germany we found a strong impact of the long term interest rate of Japan. Remarkable is that in the case of the Netherlands, we found three significant linkage effects: with Germany, France and the United Kingdom. The consumer price inflation was significant in all countries, except for Italy. The change in consumer price inflation did not yield a significant effect in any country. Remark that for the USA and Japan we included lagged consumer price inflation into the equation. This yielded better results than current consumer price inflation.

4 The historical tracking performance of the model

In the previous section we focused on reducing errors in single equations. In this section we will investigate the performance of each equation in the complete model. In order to assess the adequacy and validity of the model we present the historical simulation results in this section. To show the performance of the model over the sample period considered, we will perform static and dynamic simulations (see, e.g., Fisher and Wallis [11]). For these simulations, we present for each individual equation the the Theil inequality coefficient [6] , which is defined as

$$\text{Theil} := \frac{\sqrt{\sum_{t=1}^{t=T}(p_t - o_t)^2}}{\sqrt{\sum_{t=1}^{t=T}(o_t - o_{t-1})^2}},$$

where p_t is the predicted outcome in the static simulation process and o_t is the observed/actual value for the variable in question at time t, with t ranging from 1963 to 1991. As argued in Fisher and Wallis [11] static simulation is most appropriate for analysing the historical tracking performance. However, it is our experience that, in practice, dynamic simulation (where residuals accumulate over time) quicker traces certain misspecifications in the model than static simulation. Dynamic simulation also shows some interesting *dynamic* properties of the model, such as robustness.

In Table 9, we present the Theil inequality coefficients. Our static simulation can be compared with a one-step ahead forecast and our dynamic simulation with a one-step ahead forecast for the year 1963, a two-step ahead forecast for the year 1964,..., till a 29-step ahead forecast for the year 1991. If the Theil inequality coefficient is higher than one, the model predicts worse than the so-called naive prediction. This prediction is the prediction of no change. In our static simulation practically all figures are smaller than one. Some values for GDP inflation, growth in wages and the growth in unemployment rate are slightly smaller than one. Only the Theil inequality coefficient of the growth of the unemployment rate in Japan is considerably higher than one. The fact that in Japan the unemployment rate figures are remarkably stable during the sample period explains

[6] The root mean square errors (RMSE) and the mean average errors (MAE) ranged from 0.002-0.03. According to the classification of Brunia [4], and in comparison with the U.K. models in [11] we consider these values as satisfactory.

Table 8: Estimation results of the long term interest rates

Belgium:

$$\Delta RL^{Be} = \underset{(0.005)}{0.014} - \underset{(0.15)}{0.47} RL^{Be}_{-1} + \underset{(0.11)}{0.34} RS^{Be}_{-1} + \underset{(0.06)}{0.31} \Delta RS^{Be} + \underset{(0.11)}{0.29} \Delta RL^{Fr} + \underset{(0.032)}{0.025} \Delta P^{Be}_{c}$$

$\overline{R}^2 = 0.84$, $SE = 0.17$, $t(\hat{\rho}) = -0.00$

Germany:

$$\Delta RL^{Ge} = \underset{(0.005)}{0.028} - \underset{(0.10)}{0.71} RL^{Ge}_{-1} + \underset{(0.06)}{0.37} RS^{Ge}_{-1} - \underset{(0.08)}{0.21} \Delta RL^{Ge}_{-1} + \underset{(0.03)}{0.24} \Delta RS^{Ge} + \underset{(0.07)}{0.14} \Delta RL^{Us} + \underset{(0.08)}{0.26} \Delta RL^{Ja} + \underset{(0.054)}{0.083} \Delta P^{Ge}_{c}$$

$\overline{R}^2 = 0.90$, $SE = 0.08$, $t(\hat{\rho}) = 0.09$

France:

$$\Delta RL^{Fr} = \underset{(0.003)}{0.005} - \underset{(0.10)}{0.32} RL^{Fr}_{-1} + \underset{(0.10)}{0.27} RS^{Fr}_{-1} + \underset{(0.07)}{0.33} \Delta RS^{Fr} + \underset{(0.14)}{0.47} \Delta RL^{Us} + \underset{(0.039)}{0.056} \Delta P^{Fr}_{c}$$

$\overline{R}^2 = 0.82$, $SE = 0.25$, $t(\hat{\rho}) = -1.06$

Denmark:

$$\Delta RL^{Dn} = \underset{(0.005)}{-0.007} - \underset{(0.13)}{0.60} RL^{Dn}_{-1} + \underset{(0.15)}{0.54} RS^{Dn}_{-1} + \underset{(0.07)}{0.63} \Delta RS^{Dn} + \underset{(0.070)}{0.389} \Delta P^{Dn}_{c}$$

$\overline{R}^2 = 0.85$, $SE = 0.61$, $t(\hat{\rho}) = -1.06$

United Kingdom:

$$\Delta RL^{Uk} = \underset{(0.005)}{0.010} - \underset{(0.12)}{0.31} RL^{Uk}_{-1} + \underset{(0.09)}{0.15} RS^{Uk}_{-1} + \underset{(0.07)}{0.28} \Delta RS^{Uk} + \underset{(0.22)}{0.24} \Delta RL^{Ge} + \underset{(0.15)}{0.20} \Delta RL^{Fr} + \underset{(0.040)}{0.095} \Delta P^{Uk}_{c}$$

$\overline{R}^2 = 0.74$, $SE = 0.37$, $t(\hat{\rho}) = -0.85$

Ireland:

$$\Delta RL^{Ir} = \underset{(0.005)}{0.003} - \underset{(0.12)}{0.32} RL^{Ir}_{-1} + \underset{(0.11)}{0.23} RS^{Ir}_{-1} + \underset{(0.10)}{0.23} \Delta RS^{Ir} + \underset{(0.16)}{0.54} \Delta RL^{Uk} + \underset{(0.039)}{0.114} \Delta P^{Ir}_{c}$$

$\overline{R}^2 = 0.71$, $SE = 0.56$, $t(\hat{\rho}) = -1.78$

Italy:

$$\Delta RL^{It} = \underset{(0.004)}{0.010} - \underset{(0.11)}{0.46} RL^{It}_{-1} + \underset{(0.09)}{0.38} RS^{It}_{-1} + \underset{(0.09)}{0.38} \Delta RL^{It}_{-1} + \underset{(0.07)}{0.37} \Delta RS^{It} + \underset{(0.21)}{0.28} \Delta RL^{Ge} + \underset{(0.18)}{0.22} \Delta RL^{Fr}$$

$\overline{R}^2 = 0.81$, $SE = 0.46$, $t(\hat{\rho}) = -0.40$

Netherlands:

$$\Delta RL^{Nl} = \underset{(0.002)}{0.007} - \underset{(0.06)}{0.27} RL^{Nl}_{-1} + \underset{(0.05)}{0.20} RS^{Nl}_{-1} + \underset{(0.04)}{0.19} \Delta RS^{Nl} + \underset{(0.10)}{0.23} \Delta RL^{Ge} + \underset{(0.06)}{0.15} \Delta RL^{Fr} + \underset{(0.08)}{0.15} \Delta RL^{Uk} + \underset{(0.021)}{0.023} \Delta P^{Nl}_{c}$$

$\overline{R}^2 = 0.92$, $SE = 0.07$, $t(\hat{\rho}) = 0.32$

USA:

$$\Delta RL^{Us} = \underset{(0.003)}{0.005} - \underset{(0.08)}{0.51} RL^{Us}_{-1} + \underset{(0.09)}{0.50} RS^{Us}_{-1} - \underset{(0.12)}{0.20} \Delta RL^{Us}_{-1} + \underset{(0.06)}{0.39} \Delta RS^{Us} + \underset{(0.005)}{0.013} \Delta P^{Us}_{c_{-1}}$$

$\overline{R}^2 = 0.80$, $SE = 0.19$, $t(\hat{\rho}) = -2.08$

Japan:

$$\Delta RL^{Ja} = \underset{(0.008)}{0.012} - \underset{(0.13)}{0.35} RL^{Ja}_{-1} + \underset{(0.10)}{0.14} RS^{Ja}_{-1} + \underset{(0.07)}{0.19} \Delta RS^{Ja} + \underset{(0.13)}{0.29} \Delta RL^{Ge} + \underset{(0.037)}{0.067} \Delta P^{Ja}_{c_{-1}}$$

$\overline{R}^2 = 0.48$, $SE = 0.30$, $t(\hat{\rho}) = -0.87$

Table 9: Theil inequality coefficients

	ΔY		ΔP_y		ΔP_c		ΔW	
	static	dynamic	static	dynamic	static	dynamic	static	dynamic
Belgium	0.53	0.79	0.69	1.31	0.60	1.31	0.72	1.67
Germany	0.50	0.77	0.62	0.89	0.55	0.98	0.61	0.78
France	0.37	0.48	1.03	2.52	0.87	1.84	1.05	2.39
Denmark	0.76	1.13	0.58	1.46	0.76	1.57	0.77	1.93
U.K.	0.57	0.82	0.36	0.77	0.44	0.92	0.45	0.87
Ireland	0.54	0.65	0.64	0.66	0.63	0.87	0.83	0.77
Italy	0.58	0.67	0.79	1.46	0.83	1.43	0.67	1.20
Netherlands	0.60	0.81	0.77	1.31	0.72	1.20	0.84	1.26
USA	0.52	0.74	0.74	1.41	0.80	1.44	0.78	1.60
Japan	0.58	0.60	1.01	1.34	0.86	1.30	1.00	1.53

	RL		ΔRL		ΔN		ΔU	
	static	dynamic	static	dynamic	static	dynamic	static	dynamic
Belgium	0.40	0.45	0.34	0.44	0.77	1.12	1.01	1.47
Germany	0.31	0.37	0.24	0.41	0.59	1.01	1.03	1.76
France	0.41	0.70	0.34	0.47	0.49	0.70	0.65	0.92
Denmark	0.43	0.81	0.29	0.41	0.47	1.01	0.63	1.13
U.K.	0.42	0.71	0.33	0.33	0.48	0.86	0.66	1.40
Ireland	0.56	0.76	0.41	0.41	0.51	0.65	0.54	0.70
Italy	0.39	0.56	0.37	0.37	0.52	0.70	0.87	1.16
Netherlands	0.30	0.47	0.24	0.24	0.65	1.26	0.68	1.31
USA	0.40	0.52	0.35	0.35	0.55	0.76	0.67	0.93
Japan	0.68	0.95	0.51	0.51	0.62	0.61	2.53	2.47

most of the difficulties. In our dynamic simulations, most figures of inflation and wages are above one, but most figures of output growth, long term interest rate and growth of employment are all less than one. This is, of course, not remarkable because in dynamic simulation errors do accumulate. On average, the Theil inequality coefficients of the dynamic simulation results are less than twice the Theil inequality coefficients for the static simulation exercise. If we look at the Theil inequality coefficients as published in Fisher and Wallis [11], we see that for most U.K. models in the static simulation many coefficients are above one. Therefore, the overall impression from the shown statistics is that the model is capable of reproducing the most important developments during the sample period.

5 Shock analysis

To show the dynamic properties of the model we applied several shocks to the model. The shocks are similar to the shocks Whitley [26] applies to several large multi-country models. Beforehand, we can already stress that the striking difference with our model and the large multi-country models in [26] is the representation of the aggregate demand equation, which in our model equals aggregate supply. The fact that GDP in our model is expressed by only one estimated equation, instead of separately modelled sub-categories like consumption, investment, exports and imports, explains most of the differences. However, in order to check the qualitative properties of the model, we compare the obtained results with the outcomes of these models. Whitley's analysis [26] compares the four major European economies, Germany, France, Italy and the United Kingdom.

5.1 Single country shocks

First, we give an impression of some country-specific developments. We analyse the effects of a shock originating in a domestic country on the domestic variables of that country. In the case of a linear model, the outcomes of applying a certain shock are base independent. Therefore, it does not matter in which year the shock is applied. We used for each shock the year 1963 as the starting point. Now, for each country separately, we consider the following four shocks:

(1) Fiscal shock: a 1% of GDP shock to government expenditure.
Expenditure is raised by 1% of GDP of its base value in the years 1963-1991. The simulation is carried out with fixed real interest rates. The real interest rate in our model is fixed as follows: a new variable is introduced which replaces the term $(RL_{t-1} - \Delta P_{y_t})$ in the GDP equation. This new variable keeps his historical value throughout the simulation exercise.
(2) Wage shock: a 1% wage shock.
The wage variable is made exogenous, which is performed by skipping the wage equation in each country model. This exogonous wage variable is raised then by one percent of its base value throughout the period 1963-1991. Real interest rates are kept fixed and wage costs are held constant in all other countries.
(3) Monetary shock: a 1% nominal short-term interest rate shock.
The nominal short-term interest rate is raised by 1% point, throughout the period 1963-1991.
(4) Exchange rate shock: the dollar exchange rate is reduced by 10% below base.
This shock is applied for each country in turn during the period 1963-1991. Nominal interest rates are kept fixed. In our model several exchange rates between countries are modelled with the USA as linking country. For instance, the exchange rate between Germany and Belgium is modelled as $E^{GeBe} = E^{GeUs}E^{UsBe}$ (E^{GeBe}, the exchange rate between Germany and Belgium, is defined as the amount of German Deutschmark for one Belgian Franc). In our experiment a 10% fall of the effective exchange rate was simulated by raising E^{GeUs} by 11.11%; hence, by depreciating the Deutschmark vis-à-vis the US Dollar.

The simulation experiments in Whitley [26] are conducted on a forecast base of each model over a 6-year time horizon. The figures presented in his study are of year 1, year 3, year 5 and year 6. For each simulation experiment, Whitley [26] presents the corresponding change in output and GDP-price. Remark that, for some experiments, the figures in year 6 can be considered as long-run values. This is probably the case, if the differences between the figures in years 5 and 6 are small. For comparative reasons, we will present the figures for our model for the same years. The simulation results of the four shocks are presented in Table 10.

(1) Single-country fiscal shocks.
In our model, expanding G raises aggregate demand/output. This rise in output will raise prices, wages and employment. In most countries, the long term interest rate depends on the consumer price inflation which implies that the long term interest rate also increases for those countries (tightening monetary policy).
There is one important major difference between the simulation exercise of the existing multi-country models and our model. In our model we estimated the effect of the impact of government expenditure on output, whereas in the multi-country models this effect is simulated by raising the government expenditure component as part of the GDP identity equation. As a result, our model shows much more differentiation between the output responses of the various countries than the output responses of the large scale models in [26].
In our model the effect of a 1% increase of government expenditure is highest in the three major economies, Germany, USA and Japan. Weak responses are found for France, the United Kingdom and Italy. A negative effect in year 5 and 6 is found for Ireland. This effect is easy to explain if we go back to the estimation result of this equation. It is the only country where we could not find any evidence of a positive effect of the level variable G. This aspect clarifies that there is, even, an undershooting effect of the baseline in year 5 and year 6. Simulation shows that in the long run

TABLE 10.

	GDP				GDP PRICES			
	Year 1	Year 3	Year 5	Year 6	Year 1	Year 3	Year 5	Year 6

Fiscal Shock-single country simulations (percentage difference from base).
An increase of government expenditure by 1% of GDP and fixed real interest rates.

Germany	1.82	1.44	1.36	1.43	-0.01	0.83	1.21	1.35
France	0.40	0.34	0.33	0.33	0.08	0.33	0.65	0.77
Italy	0.21	0.47	0.65	0.71	0.10	0.73	1.67	2.18
United Kingdom	0.18	0.29	0.31	0.31	-0.10	0.09	0.30	0.38
Belgium	1.10	1.05	1.02	1.00	0.12	1.10	1.65	1.82
Denmark	0.00	0.77	1.02	1.03	0.00	0.02	0.78	1.35
Ireland	0.71	0.05	-0.21	-0.07	-0.22	-0.05	0.14	0.11
Netherlands	1.13	0.96	0.87	0.86	0.00	0.61	1.06	1.24
USA	1.23	1.89	1.35	1.27	0.00	0.51	1.13	1.38
Japan	0.00	0.94	1.59	1.88	0.00	0.35	1.13	1.51

Wage Shock-single country simulations (percentage difference from base).
Shock of 1% to wage compensation and fixed real interest rates.

Germany	0.03	-0.01	-0.01	-0.01	0.45	0.63	0.67	0.68
France	-0.12	-0.12	-0.09	-0.08	0.57	0.83	0.85	0.86
Italy	-0.05	-0.07	-0.06	-0.06	0.54	0.86	0.93	0.94
United Kingdom	0.00	-0.01	-0.02	-0.02	0.00	0.22	0.53	0.66
Belgium	-0.03	-0.03	-0.02	-0.02	0.28	0.44	0.48	0.50
Denmark	0.00	0.00	0.00	0.00	0.38	0.65	0.73	0.75
Ireland	-0.07	-0.03	0.02	0.01	0.71	0.91	0.87	0.86
Netherlands	-0.18	-0.11	-0.08	-0.07	0.60	0.64	0.65	0.66
USA	0.00	0.00	0.00	0.00	0.00	0.53	1.08	1.20
Japan	0.00	0.00	0.00	0.00	0.74	0.51	0.47	0.47

Monetary Shock-single country simulations (percentage difference from base).
Shock of 1% rise in the nominal short term interest rate for 6 years.

Germany	0.00	-0.44	-0.50	-0.48	0.00	-0.07	-0.27	-0.35
France	0.00	-0.36	-0.81	-1.03	0.00	-0.11	-0.52	-0.88
Italy	0.00	-0.20	-0.36	-0.23	0.00	-0.35	-1.04	-1.24
United Kingdom	0.00	-0.43	-0.53	-0.55	0.00	0.06	-0.31	-0.49
Belgium	0.00	-0.25	-0.60	-0.73	0.00	-0.07	-0.41	-0.65
Denmark	0.00	-0.15	-0.24	-0.26	0.00	0.00	-0.15	-0.27
Ireland	0.00	-0.53	-0.65	-0.60	0.00	0.18	0.25	0.20
Netherlands	0.00	-0.10	-0.33	-0.45	0.00	0.00	-0.09	-0.18
USA	0.00	-0.99	-0.62	-0.46	0.00	-0.12	-0.44	-0.55
Japan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Exchange-rate Shock-single country simulations (percentage difference from base).
10% fall in nominal exchange rate, fixed nominal interest rates.

Germany	-0.37	0.10	-0.09	-0.12	0.27	0.64	0.53	0.38
France	2.52	2.35	2.16	2.08	1.23	4.81	8.30	9.51
Italy	2.11	0.86	-0.36	-0.58	3.11	9.11	10.72	10.22
United Kingdom	0.49	0.37	0.23	0.17	-0.28	0.46	0.92	1.04
Belgium	1.62	1.28	1.06	0.82	2.90	6.28	7.50	7.68
Denmark	0.03	0.19	0.15	0.10	0.26	2.17	3.08	3.20
Ireland	1.51	2.24	0.20	-0.27	3.11	11.32	13.21	13.27
Netherlands	2.57	2.33	1.71	1.32	1.47	7.56	7.55	7.22
Japan	0.00	0.00	0.00	0.00	0.80	1.42	0.05	-0.31

this effect will peter out and become zero for GDP in Ireland. A possible "explanation" for this result might be that the Irish economy has done relatively well in the second half of the eighties in spite of considerable fiscal consolidation. The zero effect in year 1 of GDP in Denmark and Japan is explained by the fact that we could not find a significant effect of ΔG in our estimated equation. In all countries, except Ireland, output will be raised permanently, because the level variable G occurs in the GDP-equation.
The development of prices looks adequately and, more or less, coincides with the findings of the large models in [26]. If we compare for each country the ratio of GDP-price response and GDP-response we find in our model relatively high figures for Italy and France.

(2) Single-country wage shocks.
The only way by which wages influence output in the GDP-equation is the term of the real exchange rate. The outcome of this simulation exercise gives an indication of the effect of this variable on output for each country. In the large multi-country models there are many more ways by which wages affect output (i.e., wealth effects, consumption effects). The large models in [26] find, on average, somewhat stronger quantitative effects than our model. Qualitatively, the effect of a rise in wages on output is the same. We could not find any effects for Denmark, USA and Japan. This is due to the fact that in our estimations there was no evidence of any significant effect for the real exchange rate variable.
The effect of wages on prices is much stronger than the effect of wages on output. The results of our model coincide with the findings of the multi-country models in Whitley [26]

(3) Single-country monetary shocks.
If we look at our estimation results, we see that a rise in the nominal short term interest rate directly affects output in the United Kingdom, Ireland and the USA. In the other countries the influence of short term nominal interest rates on output is indirect. A rise in the nominal short interest rates raises the long term interest rate and this affects output. In our model, as in most large multi-country models, a rise in the nominal short term interest rates lowers output. If we look at the responses on output we find, with the exception of France in year 6, figures which are between zero and minus one. The differences between the countries are modest and certainly not as great as in the government expenditure experiment. We find no effect at all for Japan, because interest rates were not included in the GDP-equation for Japan.
In general the effect on prices is ambiguous in the first three years and negative in year five and six. An outlier is (again) Ireland which has a positive price development. The reason for this can be found in the GDP inflation equation for Ireland where we found a very strong negative effect of the change in output minus output trend. The United Kingdom starts initially with an overshooting effect, but in the long run the effects on prices are negative. The positive effect in the short run can be traced back to the wage equation where we found a strong negative effect of a change in lagged labour productivity.

(4) Single-country exchange rate shocks.
Through various channels, such as the GDP equation, the price equations (domestic consumer prices and GDP prices) and the employment equation, the exchange rate influences all the variables in our model. This experiment therefore gives an idea of the strength of these effects in our model. The output response for Germany and Denmark is low. We find strong effects for France and the Netherlands. Qualitatively, the output responses are more or less comparable to the large models (except for Germany).
The price responses between the countries in the model are quite different. For the countries France, Italy, Belgium, Ireland and the Netherlands we find strong price responses. Full homogoneity of prices in the medium term is present in the countries France, Italy and Ireland. For the large countries Germany, the United Kingdom and Japan we found very small price responses contrary to the large multi-country models in [26]. There are several reasons for these small responses. First of all, we must stress that the exchange rate in our model appears only in differences, so that in the long run there is a tendendency that effects will return back to the

baseline. Secondly, in some aggregate demand equations we found only limited real exchange rate effects.

We have now examined the two key variables in the model, output and prices for each country separately. To see whether the effects of the other key endogenous variables, such as wages, employment and the unemployment rate are similar as in the large multi-country models, we adopted an approach as developed by Hickman [16]. This approach is also adopted by Whitley [26, 27]. They suggest to decompose price-output responses (the inverse of the aggregate supply elasticity) into various ratios of key endogenous variables:

$$\Delta P/\Delta Y = \Delta P/\Delta W \cdot \Delta W/\Delta U \cdot \Delta U/\Delta N \cdot \Delta N/\Delta Y$$

The ratios of the key endogenous variables can be specified as follows (where Δ denotes percentage deviation from the base simulation):
$\Delta P/\Delta Y$: the inverse of the aggregate supply elasticity.
$\Delta P/\Delta W$: the ratio of prices to wages.
$\Delta W/\Delta U$: demand effect on wages.
$\Delta U/\Delta N$: labour force participation.
$\Delta N/\Delta Y$: movements in productivity.
One would expect that a positive sign of $\Delta P/\Delta Y$ is determined by a positive sign of $\Delta P/\Delta W$ and $\Delta N/\Delta Y$ and a negative sign of $\Delta U/\Delta N$ and $\Delta W/\Delta U$. We calculated these figures, just as Whitley [26, 27] did, for our first experiment (a rise in government expenditure). The results are presented for year 6 (as percentage deviation from the base simulation) in Table 11. These

Table 11: Contributions to the aggregate supply elasticity: year 6

	$\Delta P/\Delta W$	$\Delta W/\Delta U$	$\Delta U/\Delta N$	$\Delta N/\Delta Y$	$\Delta P/\Delta Y$	AS
Belgium	0.65	-12.1	-1	0.23	1.83	0.55
Denmark	0.52	-18.6	-1	0.14	1.31	0.76
Ireland	2.40	0.9	-1	0.42	-1.49	-0.67
Netherlands	0.60	-12.4	-1	0.19	1.44	0.69
USA	0.74	-2.0	-1	0.74	1.09	0.92
Japan	0.47	-24.6	-1	0.07	0.81	1.24
Germany	0.62	-6.1	-1	0.25	0.95	1.06
France	0.74	-5.8	-1	0.54	2.30	0.43
Italy	0.90	-10.1	-1	0.34	3.05	0.33
United Kingdom	0.71	-2.1	-1	0.82	1.23	0.81
Average of year 6 [a]	0.66	-10.4	-1	0.37	1.56	0.75
Average of year 29 [b]	0.80	-14.1	-1	0.39	2.81	0.47
Average in [26, 27] [c]	0.85	-5.09	-0.74	0.73	2.15	0.47

a. Results are subject to rounding. The contribution of Ireland is excluded from the average. Furthermore, all variables are measured as percentage difference from base (except unemployment rate, absolute difference from base). The value for the aggregate supply elasticity is indicated by AS and is defined as $1/(\Delta P/\Delta Y)$.
b. These are the averages (excluded Ireland) of year 29, which give a good indication of the long run properties of the model.
c. These are the averages of year 6 as published by Whitley [26, 27].

figures show that the contributions of most endogenous variables are qualitatively within range and coincide with the figures as presented in Whitley's paper. As stressed in Whitley [26, 27] the figures should be treated with care, but, as he claims, it can be useful *in some cases* to highlight particular differences in structure of certain models. Most figures seem quite acceptable with some outliers. In Ireland $\Delta P/\Delta Y$ is negative and this can be traced back to the fact that in Ireland there is no level variable of G, government expenditure, in the equation. As can be seen from Table 6, ΔY was negative which indicates an undershooting effect. This effect influenced all other ratios of Ireland in the Table. For the other nine countries, the Table shows some interesting properties. If we look at the averages of year 6 and compare them with the averages of Whitley [26], we see that our country models exhibit weaker inflationary effects from a demand expansion, implying a flatter aggregate supply schedule in the medium term. In the long run the aggregate supply elasticity is lower and equals the elasticity as given by Whitley [26]. Furthermore, a striking difference with the multi-country models is the lower ratio of movements in productivity, implying that an aggregate demand shock has only limited power to raise employment. This is more in line with the history of the past 40 years, where productivity has gone up more or less steadily, and unemployment has shown little trend (see Blanchard [2]). In our model, a shock of government expenditure affects employment mainly in the short term. A major reason for this finding is that we did not impose any restriction in the employment equation. Strongly related with the ratio of movement in productivity is the high (negative) elasticity of the demand effect on wages. Remark also that in the medium term (year 6) the ratio of prices to wages is lower than the average published by Whitley [26]. In the long term (year 28) the elasticity is higher which is an indication that most effects have not settled down after 6 years.

5.2 International linkages

An important aspect of the model is that it is capable to show various external effects when there is a change of a domestic macroeconomic policy. In this section we will concentrate on these spillover effects. One of our goals was to construct a model that contains strong international linkages. To show this aspect of the model, various shocks will be applied. To save space we restrict ourselves to four shocks. With these shocks we analyse the spillover effects to other EU-countries from a single country's expansion.

The four shocks we apply are the following:

(1) Fiscal shock USA:

2% GDP shock to government expenditure, throughout, in the USA is applied to the model. Real interest rates are kept fixed for all the countries.

(2) Fiscal shock Germany:

2% GDP shock to government expenditure, throughout, in Germany is applied. We analyse the effects of most of the endogenous variables of the model. In order to compare certain effects with the shock in (1) we keep the real interest rates fixed.

(3) Monetary shock in Germany:

2% short-term nominal interest rate shock in Germany. The nominal short-term interest rate of Germany is raised 2% point, throughout the period 1963-1991.

(4) Exchange rate shock to the US dollar vis-à-vis all other currencies:

A depreciation of the US dollar, throughout, by 10% vis-à-vis all other currencies. This experiment is done in the same way as explained in the single country experiments but now we depreciate the US dollar against all currencies at once. As in the Whitley experiment [26], we keep nominal interest rates fixed. The simulation results of the these four shocks are presented in Figures 12-17.

(1) Fiscal shock USA.

The effect of the USA on other economies in our model corresponds (roughly) during the first three years with the findings of the other large scale models as mentioned in Whitley [26]. Again we have to stress that in each country foreign influences are modelled as differences (and not in levels), so, in the long run the effect on foreign output will return to its baseline. This model property corresponds to the output figures for our model in years five and six. Remarkable is that all countries in Figure 12 show cyclical behaviour in their GDP figures, which is due to the cyclical output response of the USA. In our model, the first year effect of an increase in government expenditure in the USA on the foreign countries lies between 0.12 % and 0.46 % of USA GDP-output. The United Kingdom profits most, and Italy least.

FIG. 12. Output responses after USA government expenditure shock

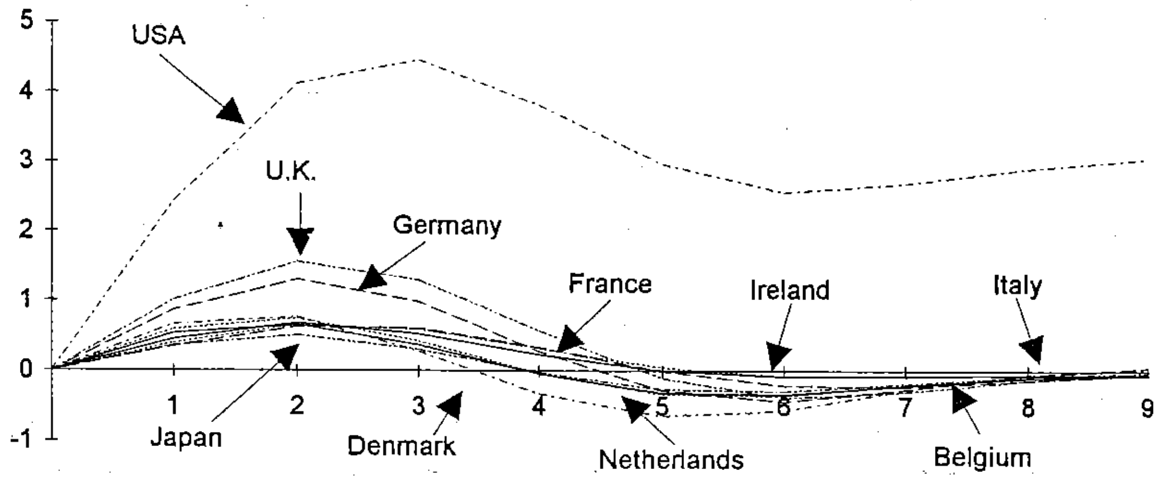


FIG. 13. Output responses after German government expenditure shock

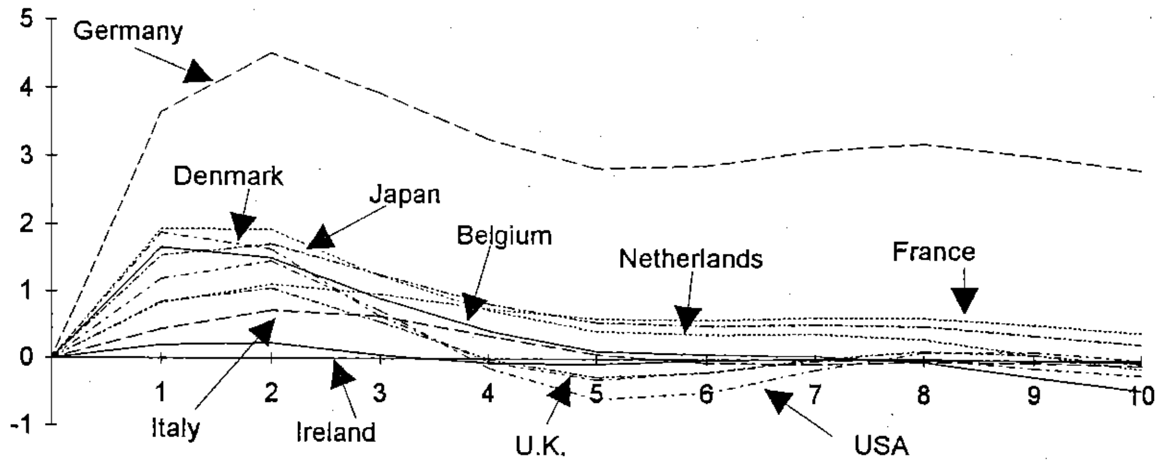


FIG. 14. GDP price responses after German government expenditure shock

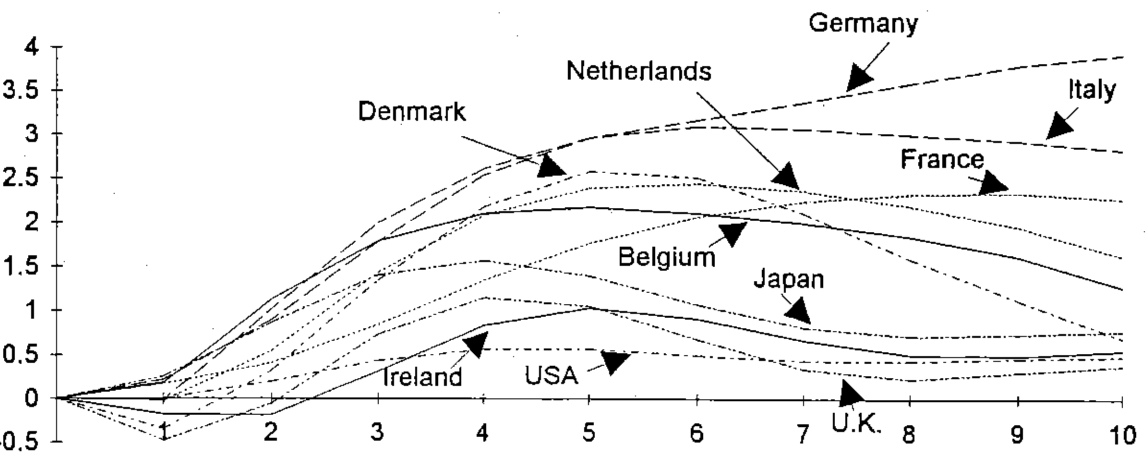


FIG. 15. Output responses after ~~a decrease~~ an increase in the German short term interest rate.

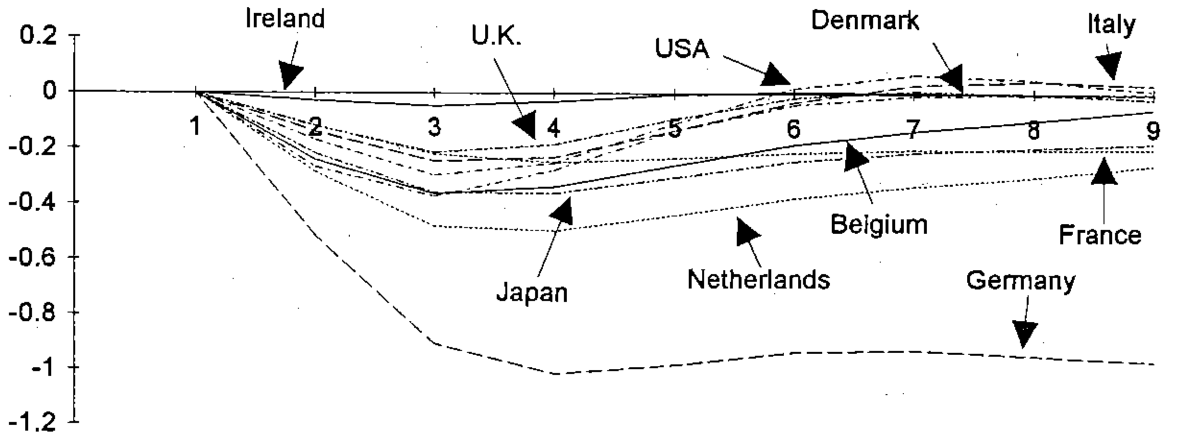


FIG. 16. Output responses after a depreciation of the US Dollar by 10% against all currencies.

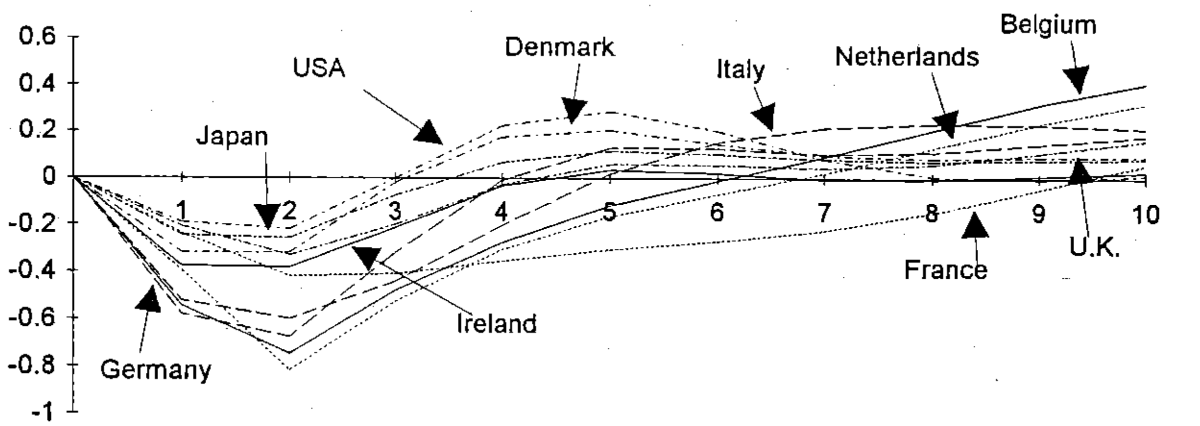
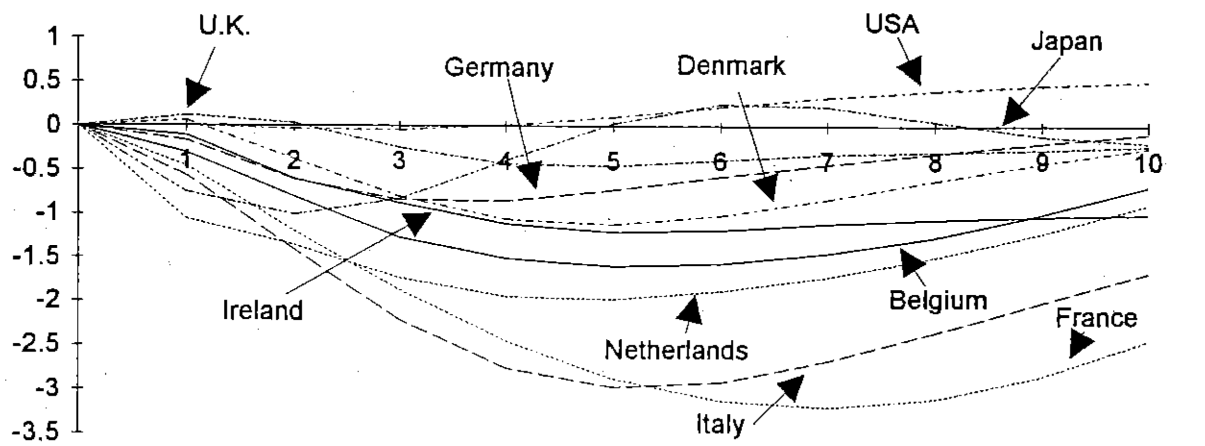


FIG. 17. GDP price responses after a depreciation of the US Dollar by 10% against all currencies.



The development of the prices (not listed here) is qualitatively also comparable with the outcomes of the models in Whitley [26]. On average, quantitatively, the price responses are weaker than predicted by the multi-country models [26]. Most price responses are lower than 1% in year 6 which is explained by the low output response in the medium term, which surpresses the price development.

(2) Fiscal shock Germany.

Considering the size of the effect (first year GDP output of Germany is higher than first year GDP output in the USA. See our previous experiment) we find various interesting results. First of all Figure 13 shows that small open economies like the Netherlands, Denmark and Belgium, are heavily affected by a German expenditure shock. If we again compare the effect in the first year we find that the effect of a German expenditure shock on the foreign economies lies between 0.07 % and 0.53 % of German GDP-output in the first year. Remark that also in this experiment there is some cyclical behaviour in the medium term and long term. In the long run, most effects peter out to a very small (positive) value.

As Figure 14 shows, the development of prices is quite strong in most EU-economies. Only the prices in the USA, Japan, U.K., and Ireland seem to be less affected by the German government expenditure shock. Note also that most countries which are affected by the shock have their highest price response around year four and five. Note that the output response in Italy in Figure 13 was rather low whereas the price response in Figure 14 is relatively strong, which is due to the interaction terms ΔP^{ItGe} in the two price equations of Italy.

(3) Short term interest rate shock Germany.

Note, that in this experiment we do not have fixed real interest rates; so we have an additional feedback transmission mechanism in the aggregate demand equation through prices in the real interest rate term. As a consequence, output responses peter out less quickly than in the previous government expenditure experiments. We see in Figure 15 that in year 2 output responses are negative in all countries and range from 0.06% till 0.55% of German GDP output in the second year. If we exclude Ireland, we see that this effect is still visible in year 5, where the output responses range from 0.09% till 0.45% of German GDP output in year 6. It takes some time before prices respond. In general countries with high output responses show high price responses.

(4) A depreciation of the US dollar by 10% against all other currencies.

By applying this external shock, we expected that an initial depreciation of the US dollar would lower output in the EU-economies as a result of weakened trade competitiveness. Some of this reductioned output might be weakened by the initial expected increase in US demand. As a consequence, prices are expected to fall in the EU-economies. This pattern is clearly visible in Figure 16 and 17 in the short term. All EU-economies show a negative output and price response. The size of the output responses are moderate and are (in absolute size) never higher than 1%. A major reason for this is the negative response of GDP output in the USA in the first three years, which is due to the direct link in the aggregate demand equation of the USA with Germany. It takes some time before this negative effect is offset and output becomes positive in the USA after year 3. Because of this positive output response in the USA, almost all countries show an output level rise after year 3 and some output responses even get strongly positive in the long run.

In Figure 17 we see that for all the EU-economies prices do fall during the whole period, where Italy and France show the strongest price responses. The direct price link between Japan and the USA in the model evokes the positive price response in the medium term in Japan.

6 Conclusions

In this paper we presented SLIM, a Small Linear Interdependent Model of eight EU-economies, the USA and Japan. The model is of the Mundell-Fleming type and contains six behavioural equations and is estimated with yearly data from 1960 to 1991. The main feature of the model is that direct linkages among countries are explicitely modelled. The model contains international linkages in five of the six equations; namely the equation for the long term interest rate, the two price equations, the GDP equation and the employment equation. The model is designed such that we adopted the same broad specification for the different countries and that the estimation process decides about the strength of certain structures in the model. The same approach is also used for the direct linkages; the estimation process determines the strength of certain linkages. These linkages are modelled such that more emphasis is put on short term effects than on long term effects. The results of the historical tracking performance indicate that our model is capable of reproducing the most important economic developments during the sample period.

Although no stock adjustment and, hence, no integration wealth effects are considered ab initio, the starting point of our interdependent modelling exercise was a Mundell-Fleming model. The basic model is extended in various ways:
i) to include more than two countries (10 countries in our case), where the countries with the largest trade shares determine the direct linkage specification;
ii) flexible prices, indicating imperfect competition on the goods, labour and capital markets, are incorporated in the equations for output prices, consumer prices, wage rates and long term interest rates;
iii) a labour market part was supplemented, determining a labour demand function, an unemployment function and corresponding prices for labour and output, where the underlying production function is of the Cobb-Douglas type; these equations form the supply part of the model;
iv) finally, a dynamic formulation, allowing for a partial adjustment and an error correction mechanism, was applied.

It is clear that using a Mundell-Fleming type of model as a starting point may be more representative for some countries than for other countries. Our experience was that the yearly data of small countries like Belgium, the Netherlands and to a lesser extent Denmark *fit* fairly well into this framework. Larger countries like Germany, France and to a lesser extent Italy did also reasonably well. We found major problems for two countries: the United Kingdom and Ireland. For the United Kingdom we had many problems finding suitable aggregate demand, price and wage equations. Our simulation results for Ireland involve many opposite results as expected from the theoretical Mundell-Fleming model. The models of two outside economies, the USA and Japan, should be treated with more care because we ignored for these countries some important trading partners. Taken this into account the outcomes for the USA were satisfactory whereas for Japan we had large problems finding suitable aggregate demand, price and employment equations.

Through shock analysis our model is compared with five multi-country models as operating in 1992 at several EU-institutions. With our simple linear model, it is possible to generate (more or less) the same outcomes of some of the main key macroeconomic variables as modelled in large multi-country models. The main differences of our model with the large multi-country models are as follows:
i) An output shock in a country has only little responses for employment in that country, and this effect tends to zero in the long run. One of the main reasons for finding this effect is that we did not impose any restrictions in the employment equation.
ii) For most countries, we find less inflationary effects from a demand expansion which implies a fairly flat aggregate supply schedule in the short and medium term.
iii) In the fiscal shock experiments we find more differentiation between countries, which is due to the fact that we estimated the effects of government expenditure in the aggregate demand equation.
iv) A global external fiscal shock of one of the major EU economies has (more or less) the same effect on other EU economies as a fiscal shock originating in the USA. Furthermore, the quantitative size of these shocks are in the short run more substantial and range (roughly) in the first year between 0.03%-0.87% GDP output of the country originating the shock.
v) A depreciation of the US Dollar by 10% against all other currencies has only a modest negative effect on output and prices for all EU countries in the short and medium term.

Some country specific arguments, which appear to be striking in our model, are summarized as

follows:
i) An expansive domestic fiscal policy seems to be favourable for the larger economies, the USA, Japan and Germany.
ii) There exist strong long run price-responses, after applying a wage shock, in the USA and Italy, and weak price-responses in Belgium and Japan.
iii) The effect of a monetary expansion on prices is negative in all countries, except for the price responses in the United Kingdom and Ireland, which are slightly positive in the short run.
iv) The effects of a domestic nominal exchange rate shock on output prices is rather low in the three large economies Germany, the United Kingdom and Japan.
v) The small open economies Belgium, Denmark and the Netherlands profit most from a shock originating in Germany. Belgium, the Netherlands and the United Kingdom profit most from a shock originating in France.
vi) A fiscal expansion in the USA has a large effect on the British and German output and a small effect on the Italian output, but a larger effect on Italian prices.

It should be stressed that most of these findings are model dependent. The modelling strategy used, concerning external effects, is that all external influences are measured by growth figures. This may be a somewhat broad measure and covers also external effects which may be caused in the past by factors which are common to many EU-economies. However, we believe that through the strong desaggregation of the large multi-country models, important indirect external effects may disappear. In these models trade volumes are linked through export and import volumes whereas in our model GDP volumes of the various countries are linked. The first method has the disadvantage that it neglects certain effects, such as foreign investments and knowledge. For instance, an invention which stimulates growth in one country can be copied by another country which stimulates growth in that country as well. Such indirect spillover effects are not necessarily captured if one considers only trade volumes. Furthermore, the increasing integration process of the EU-economies makes it likely that strong external effects will become more and more likely in the (near) future which makes it necessary to study models which contain strong (direct) linkages. The model in its present form can be used as a starting point for further extensions, such as the inclusion of endogenous exchange rates and intertemporal elements, such as wealth effects, a government budget constraint and a balance of payments relationship. Furthermore, because its size and its linearity, the model is useful for dynamic game applications. These aspects will be investigated in the future.

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A Appendix: description of data and data source

Our data source contains yearly data from 1960 till 1991. Most of the data are taken from the OECD: OECD Economic Outlook 53, Statistics on microcomputer diskette nr. 53, with the exception of government expenditure and real taxes (or receipts government), which we took from the European Economy 51 (EE 51), May 1992. The data for the short term interest rate are taken from the IFS 92 (International Financial Statistics 1992). The short term interest rate data are not very reliable for the period 1960-1970 where we sometimes had to rely on the discount rates. Below we will give an exact description of the data for each variable separately, and, subsequently, we will give for each country separately the way how we constructed the missing data.
Y : Gross national/domestic product, volume (OECD: GDPV)
G : Total expenditure General Government (EE 51, given as percentage of Y)
T : Current receipts General government (EE 51, given as percentage of Y)
RS : Nominal short term interest rate (OECD: IRS, if missing: IFS 92)
RL : Nominal long term interest rate (OECD: IRL)
E : Exchange rate (OECD: EXCH)
P_y : Deflator for GDP at market prices (OECD: PGDP)
P_c : Deflator for consumer expenditure (OECD: PCP)
W : Wage compensation per employee, private sector (OECD: WSSE)
L : Labour force (OECD: LF)
N : Total employment (OECD: ET)
U : Unemployment rate (OECD: UNR)
Most data are available, however there were some specific problems for W and RS. For W we followed the approach of Heylen [15]. If W was missing, we used as representative growth rate for W the growth rate of compensation per employee in the total economy which are listed in the European Economy. The assumption made is that during that period the growth rate of both variables is identical. For the RS we relied on IFS data, where we took the discount rate or money market rate. Finally, the trend output was constructed from the gross GDP variable, trend output was calculated with the following regression: $Y = \alpha_0 + \alpha_1 \text{time} + \alpha_2$ DUM7475$+\epsilon_t$, where DUM7475 is one during the years 1960- 1973 and zero during the years 1974-1991 (see, e.g., Perron [22]). The explanation for the dummy DUM65 in the employment equation in Italy is explained by Heylen [15]: "Dummy for the extensive government program to fight the recession of 1963-64 (OCDE, April 1966, pp. 11-14.)." Heylen [15] also explains the dummy DUM70 in the wage equation of Germany: "Dummy variable captures the effects of the deteriotion of the social climate (e.g. wildcat strikes in the autumn of 1969) and growing union militancy (to reverse the trend of declining labour shares) (OECD , Perspectives Economiques, Paris, OCDE, June 1971, pp. 13-14)."

Country specific remarks:
Belgium: Data on W were only available since 1970. For the 1960s we used the approach as given above. The exchange rate E was also only available since 1970, for the 1960s we used IFS data (market rate, wf).
France: Data on W for 1960-1962 is based on the European Economy and for RS, from 1960-1969, we used IFS data (money market rate, 60b).
Denmark: OECD Data for RS was only available from 1979, so before that period we used IFS data (discount rate, 60).
Germany: All data, as indicated above, available.
United Kingdom: Data on W was missing for the period 1960-1961; for these two years we used the the approach as stated above. For the RS we used from 1960-1969 IFS data (Eurodollar rate, 60d).
Ireland: IFS data for the RS was used from 1960-1969 (discount rate, 60).
Italy: For the RS we used from 1960-1968 the discount rate (60) and for the period 1969-1970 the money market rate (60b) of the IFS data.

Netherlands: For the period 1960-1969, W was calculated as stated above.
USA: All data as given above available.
Japan: For the period 1960-1964, W was calculated as stated above. For 1960-1968, RS was taken from the IFS data (money market rate, 60b) and for 1960-1962, we used IFS data (lending rate, 60p) for RL. Not available where als government expenditure and taxes for the years 1960-69. These where approximated with calculated growth rates. These growth rates were calculated with the use of OECD data, where government expenditure is calculated from current disbursements of government (YPG) and taxes from current receipts of government (YRG).

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