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EUROPEAN UNIVERSITY INSTITUTE
Department of Economics

# On International Business Cycles

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**A mis padres**

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# Introduction

Le bon sens est la chose du monde la mieux partagée: car chacun pense en être si bien pourvu, que ceux même qui sont les plus difficiles à contenter en toute autre chose, n'ont point coutume d'en désirer plus qu'ils en ont.

René Descartes

Almost all economies experience fluctuations of different intensity and duration. These fluctuations can last from one day to several years, but there is an important type of fluctuations that seems to be recurrent and periodical. These are fluctuations that last approximately from three to eight years, and that have been named in the literature "business cycles". Business cycles are also important because they are the kind of fluctuations that are best perceived by non-economists (everybody is aware of periods of recession or boom without any need for rigorous economic analysis) and also the ones that may more deeply affect the behavior of households and firms.

From a descriptive point of view, business cycles vary considerably in terms of amplitude and duration and no two cycles seem to be alike. However, they also contain a great deal of regularities. Furthermore, there is a clear tendency among developed economies to move together, that is, there seems to be a world component to business cycles.

This thesis tries to ask the following question: Are the developed economies really moving together? And, if this is so, why? The theoretical apparatus that we use to answer this question belongs to a branch of the macroeconomics literature denominated Real Business Cycle theory. This theory tries to explain economic fluctuations within a general equilibrium framework. The revival of the interest on the business cycle after Lucas (1977) and the seminal paper by Kydland and Prescott (1982) initiated this research program that has developed extensively to cover almost all areas of macroeconomics. One of the last areas to which this research program has arrived is that of open economy macroeconomics. Papers by Dellas(1986), Stockman and Svensson (1987) and Cantor and Mark (1988) led the way in applying general equilibrium theory to open economy macroeconomic issues, and the questions were finally introduced into the Real Business Cycle research program by Backus, Kehoe and Kydland (1992).

This thesis contributes to this literature in several ways. After describing the methodology, we present in Chapter 1 a collection of stylized facts of the international business cycle that we will use to motivate our theoretical research and to check the implications of the theory.

We do so very briefly because several authors, including Danthine and Girardin (1989), Backus and Kehoe (1992), Ravn (1993), Christodoulakis et al. (1993) or Fiorito and Kollintzas (1994) have extensively documented the features of international business cycles. However, our effort is worthwhile because we use a different and extended data set. Once we have described the main characteristics of international business cycles, we present two basic models (Backus, Kehoe and Kydland (1992) and (1993)) that constitute the starting point for our research. In these models, a perfectly competitive economy fluctuates in response to a technology shock and the dynamics of capital accumulation together with the consumption/saving/labor supply decisions of individuals act as transmission mechanisms of shocks. In a framework of perfect goods and capital markets, agents trade internationally to smooth consumption and equalize the world interest rate. These benchmark models enable us to understand the dynamics of these type of economies, analyze where the theory fails and point out possible directions for improvement.

These two models and their extensions leave three main unexplained puzzles. The first one concerns the behavior of foreign trade variables, in particular the terms of trade: standard models are unable to replicate the volatilities of imports, exports and the terms of trade. The second one is what we call the "risk sharing" puzzle: while we observe in reality that cross-country consumption correlations are lower than the corresponding output correlations, the models we analyze systematically produce the opposite result due the optimizing behavior of consumers and the assumption of perfect capital markets. Finally, models are unable to replicate international comovements. Economies tend to move together, and therefore we obtain positive cross-country correlations in actual data of output, investment, labor, imports and exports. However, the models tend to produce negative cross-country correlations due to the existence of a single source of dynamics and the free movement of resources.

In chapters 2 and 3 we propose two modifications of the standard model with the aim of solving some of these puzzles. In Chapter 2 we break the assumption of perfect competition by introducing increasing returns to scale and imperfectly competitive firms. Imperfect competition amplifies the effects of technology shocks in output, investment and labor variables, and produces interesting modifications in the dynamics of the model, in particular in international comovements. We also consider the effects of government spending shocks under perfect and imperfect competition, and analyze the performance of the model in relation to issues like the "twin deficits". Finally, we explore whether exogenous variable markups can explain the main features of the business cycle. The results of Chapter 2 are promising, but still our best specification fails to capture all the salient features of OECD economies. Therefore, in a joint work with Fabio Canova, we modify in Chapter 3 the model in another direction. We retain the assumption of perfect competition but introduce a feature that is becoming increasingly popular in modern macroeconomics: household production. Agents derive utility from home-produced as well as market-produced consumption goods and derive disutility from working at home as well as in the market. This adds to the standard intertemporal leisure/market-work substitution the intratemporal home-work/market-work substitution effect. In addition, the home produced good is non-tradable, and therefore we are affecting two crucial features of the model, as are labor and trade dynamics, with only one device. When household production is introduced in the model we are able to replicate the domestic features of international business cycles and at the same time generate lower degrees of risk sharing and positive international comovements. However, the model still cannot replicate the behaviour of the foreign trade variables.

Finally, in Chapter 4 we conduct an empirical exercise to analyze one of the crucial issues of international business cycles: the risk sharing issue. The motivation for this exercise is the current debate about the degree of consumption risk sharing existing in the European Union (EU), and whether or not the EU should provide some specific insurance schemes.

Complete risk sharing implies that economies should not react to idiosyncratic shocks and should react to common shocks only to the extent that the aggregate does, and this may be a crucial property if the European Union is ever to become a common currency area. Therefore, we explore the degree of risk sharing that now exists in the European Union. We propose an innovative way of testing for risk sharing: we compare the impulse responses of each country generated through VARs that contain a range of plausible shocks impinging on the economies. The result is that the level of risk sharing in the European Union seems to be reasonably high and that no specific insurance scheme seems to be needed in order to proceed further towards the European Monetary Union. However, policy measures seem to be needed to solve the structural divergences that we find related to the reactions of the different countries to the idiosyncratic variables, but it is to be noted that this issue should be related with institutional redesign and redistribution of income and not with specific insurance programs.

# Methodological Issues and Basic Assumptions

After some decades of Keynesian economics devoted primarily to comparative static analyses and stabilization policies, the 80s saw the rise and revival of the Real Business Cycle (RBC) theory. This theory is concerned with the causes and nature of economic fluctuations in dynamic perfectly competitive rational expectations economies. Contrary to the Keynesian paradigm, RBC theory views cycles as the optimal response of agents to real disturbances, such as random fluctuations in factor productivity, in a framework of frictionless competitive markets and without the need to resort to arguments relating to price stickiness or coordination failures.

Following the approaches of Frisch (1933) and Slutsky (1937), RBC theory distinguishes between the impulse and the propagation mechanism. The main impulse that this theory considers is a (supply-side) productivity shock [1]. After the influential work by Solow (1956, 1957), productivity is identified as a measure of technical progress. This measure of technical progress has been named the 'Solow Residual', and captures the growth in output that cannot be accounted for by the growth in capital and labor.

Demand-side impulses, such as economic policy or preference changes, are regarded by this theory as having no major influence on the business cycle, this therefore distinguishing clearly the approach from the Keynesian tradition.

A second important distinction with the previous macroeconomic tradition comes from the fact that, traditionally, short-term and long-term economic behaviour were studied with different theoretical and empirical tools. Important developments in growth theory, such as Brock and Mirman's (1972) optimal growth in an economy with stochastic productivity shocks or the introduction of the labor-leisure choices into the basic model, paved the way for thinking about growth and fluctuations within the same theoretical framework. Therefore, the neoclassical model of capital accumulation augmented by exogenous technology shocks became the basic framework for modern business cycle analysis. This approach shares the view of modern growth theory that simple artificial model economies are a useful way of assessing the determinants

[1] The origin of these shocks is not very well specified in the literature. Variations in productivity could come, for example, from shifts in exogenous technological possibilities or shifts in policy variables under control of the government, see Hansen and Prescott (1993) for a comment.

of business cycles and can be utilized as laboratories for the study of the effects of economic policies.

We can summarize the essential features of prototype RBC models as:

- Representative agents
- Optimization of objective functions subject to constraints
- Rational expectations, complete markets and symmetric information
- Impulse mechanism: exogenous shocks to the Solow residual
- Propagation mechanisms:
  - Intertemporal substitution of leisure
  - Consumption smoothing
  - Lags in the investment process
  - Use of inventories to meet unexpected changes in demand

Therefore, the basic RBC model is a general equilibrium model in which there is an economy populated by an infinite number of identical, infinitely lived agents that produce a single good. Consumers maximize an additively separable utility function

$$U_t = E_t\left[\sum_{i=0}^{\infty} \beta^i u(C_{t+i}, L_{t+i})\right] \tag{0.1}$$

that depends on consumption ($C_t$) and leisure ($L_t$) and a discount factor ($\beta$). The endowment of time is $H_t$ each period, which constrains leisure to be between 0 and $H_t$. The single good ($Y_t$) is produced with a constant returns to scale technology that combines capital ($K_t$)and labor ($N_t$) supplied by the households

$$Y_t = A_t F(K_t, N_t) \tag{0.2}$$

Technology shocks are represented by $A_t$, a stochastic process that shifts the production function and alters total factor productivity, which is assumed to follow a stationary Markov process. The capital stock accumulates according to

$$K_{t+1} = (1-\delta)K_t + I_t \tag{0.3}$$

where $0 < \delta < 1$ is the depreciation rate and $I_t$ is gross investment [2]. Finally, the economy faces an aggregate resource constraint

[2] The seminal Kydland and Prescott (1982) paper included three other features: a 'Time to build' structure, according to which the investment process takes more than one quarter to be finished; inventories are included as a factor of production, and agents observe a noisy signal of the productivity shock.

$$Y_t = C_t + I_t \quad (0.4)$$

The First and Second Welfare theorems show that for this economy under fairly general assumptions the solution to the social planner's problem is the competitive equilibrium allocation. Moreover, Stokey et al. (1989) demonstrate that if agents discount the future then there is a price system that supports the optimal allocation. Therefore, the model we have described is a competitive equilibrium economy because we can represent the paths of consumption, investment, output and hours as the outcome of individual households responding to prices. This methodology applies to economies with homogeneous households and no distortions, and thus rules out the presence of externalities, distorting taxes or cash-in-advance constraints (see Cooley (1995) and references therein for methods applicable to some of these issues). Brock and Mirman (1972) showed that, if the $\{A_t\}$ are identically distributed random variables, a solution to the social planner's problem for this class of economies exists. Therefore, the equilibrium of this class of models can be obtained by assuming that the economy is governed by a benevolent social planner that chooses sequences for consumption, labor supply and capital stock that maximize (0.1) subject to (0.2), (0.3) and (0.4) given the initial endowment of capital.

Kydland and Prescott (1991b) indicate the steps needed to apply general equilibrium methods to the quantitative study of business cycle fluctuations. They involve defining the question at hand, setting up and calibrating the model and reporting the findings. In what follows we address in some detail these steps.

## What is the problem we want to address?

### Reporting of facts

In order to properly analyze the business cycle properties of the data and to identify the problem that we want to address, we need a consistent way of reporting these properties. After the influential work of Hodrick and Prescott (1980), the RBC research program has chosen to characterize the behaviour of macroeconomic variables over the business cycle with a small set of summary statistics, usually a subset of first and second moments.

Simplicity in the selection of the statistics is justified on the grounds that it gives an adequate summary of the set of complex dynamics underlying the economic activity, allows a rough calculation of the magnitude of fluctuations and guides researchers in the modelling of these fluctuations. However, this approximation to the behavior of the series may be too rough and some researchers have looked for different ways of reporting BC statistics, using alternative devices such as the variance decomposition (Canova and Dellas (1992)), impulse responses (Canova (1993a)) or spectral decompositions (Gerlach (1988)).

**Detrending issues**

Many macroeconomic time series are nonstationary. The computation of moments requires the delicate issue of filtering the data in order to isolate the business cycle elements from the slowly evolving secular trends and the rapidly varying seasonal or irregular components.

There is a main problem connected with detrending which is the definition of the business cycle. Lucas (1977) defines the business cycle as the fluctuations of aggregate output around its long run trend. However, researchers disagree on the properties of the trend and its relationship with the cycle, and therefore different detrending methods imply different concepts of business cycles (see Canova (1993b) for a complete analysis of this issue).

Among the many procedures available, RBC researchers have mainly used the Hodrick and Prescott (1980)(HP) linear filter. The properties of this filter have been investigated by many authors including Canova (1993b) and (1994a), King and Rebelo (1993), Harvey and Jeager (1993), Maravall (1993), Baxter and King (1994) and Cogley and Nason (1994). This filter represents the trend component of a series with a smooth nonlinear function of time and assumes that the trend and the cyclical components of the series are independent. An estimate of the trend component of the series ($TR_t$) is obtained by minimizing for a given $\lambda$

$$\min_{[TR_t]_{t=1}^T} \left[ \sum_{t=1}^{T} C_t^2 + \lambda \sum_{t=1}^{T} ((TR_t - TR_{t-1}) - (TR_{t-1} - TR_{t-2})) \right]^2 \tag{0.5}$$

where T is the sample size and $\lambda > 0$ is a smoothing parameter that penalizes the variability of the trend. This filter renders stationary any time series that is integrated of order four or less and acts as a high-pass filter that passes cycles of frequency eight years or less when the smoothing parameter is $\lambda = 1600$. It has also the property of yielding similar results as the approximate band-pass filter proposed by Baxter and King (1994), which was designed to extract NBER cycles (i.e., those components of the data with periodicity between six and thirty-two quarters).

However, there are problems related to this practice. First of all, the smoothing parameter $\lambda$ is not estimated but chosen a priori. Hodrick and Prescott selected a value of $\lambda$= 1600 for quarterly series with the motivation that it would eliminate fluctuations at frequencies lower than 32 quarters. Baxter and King (1994) show that this filter with $\lambda = 1600$ is a reasonable approximation of a high-pass filter for quarterly data. However, for annual data, the customary values of $\lambda = 100$ or $\lambda = 400$ produces very different results from the ideal band-pass filter, and even with $\lambda = 10$ (a value preferred by Hassler et al. (1992) ) the results are not convincing.

Secondly, some authors, including Maravall (1993) and Cogley and Nason (1994), have argued that the Hodrick-Prescott filter can produce spurious cyclical patterns to data. Some authors have also argued that the stylized facts are sensitive to the choice of the filter, although empirical evidence (see Kollintzas and Fiorito (1994) or Englund et al. (1992) among others) has shown that the choice of the filter makes little difference to the results.

These problems with the Hodrick-Prescott filter have induced researchers to examine alternative detrending methods. The most popular are First Order Differencing, Linear Detrending and Beveridge-Nelson (see Canova (1993b) for an exhaustive analysis of different univariate and multivariate detrending methods applied to business cycle analysis) [3]. However, recently Baxter and King (1994) have found both First Order Differencing and Linear Detrending to be not desirable business cycles filters because they are very bad approximations to an optimal business cycle band-pass filter. An alternative view of the business cycle is that of Beveridge and Nelson (1981) who, following the work of Nelson and Plosser (1982), proposed a method that assumes that the trend and cyclical components are perfectly correlated. However, this method relies on the estimates and forecasts of ARIMA models, and therefore carries with it all its problems.

Finally, based on the NBER criteria, Baxter and King (1994) propose an optimal business cycle filter that would be for quarterly data either a band-pass filter which admits frequencies between 6 and 32 quarters or a high-pass filter which pass frequencies between 2 and 32 quarters. For annual data, instead, both high-pass and band-pass filter are the same and pass frequencies between 2 and 8 years.

## Selection and solution of the model

Once we have a clear idea of the problem we want to examine, we have to select and solve the model with which we will address the problem. RBC models are highly nonlinear models that rarely have an analytical solution [4] and therefore have to be approximated for a solution to be found. The model will then be simulated and judged by comparing BC facts of model-generated data with actual data.

### Approximation method

The same kind of disagreement found regarding the best filter to be used for detrending can also be found with respect to the selection of the approximation method (See the January 1990 issue of the Journal of Business Economics and Statistics for a complete analysis). Among all the methods available, the most popular ones are Value Function Iteration, the Linear-Quadratic approximation and the Euler equation approach.

The Value Function Iteration approach uses the tools of dynamic programming to obtain the Bellman equation of the model. Then, by iterating on the value function for every possible point

[3] The simplest method, Linear Detrending, assumes that the trend and the cyclical components of the series are also uncorrelated and that the trend follows a deterministic process that can be approximated by a function of time. The trend of a series $\{X_t\}$ can be found by fitting $\{X_t\}$ to a constant and a scaled polynomial function of time using least squares and taking the predicted value of the regression. The First Order Differencing procedure assumes that the trend component is a random walk without drift, the cyclical component is stationary and the two components are uncorrelated.

[4] An exception is the case with logarithmic utility, fixed labor input and 100 % rate of depreciation of capital, as in Long and Plosser (1983), Cantor and Mark (1987, 1988) and Dellas (1986).

of the state variables, the system will converge to the value function that solves the Bellman equation.

The Linear-Quadratic approximation suggested by Kydland and Prescott (1982) consists of substituting the technological restrictions in the objective function of the agent and then taking a second order Taylor expansion around steady state values. This linear-quadratic problem can then be solved to obtain the optimal decision rules (see Hansen and Prescott (1991) for a detailed explanation of this method).

Finally, the Euler equation approach takes advantage of the fact that the system of first-order conditions obtained from the model implicitly defines the equilibrium prices and quantities as nonlinear functions of the model state variables. Therefore, these methods consist of algorithms to solve this nonlinear system of equations and obtain the equilibrium decision rules. A particular application of this procedure is the algorithm developed by King, Plosser and Rebelo (KPR)(1988c) and generalized by Baxter (1991a) that log-linearizes around the steady state the set of first-order conditions. Dotsey and Mao (1992) have shown that this method is quite accurate for the neoclassical model when shocks are of realistic size.

**Calibration**

The second stage is to choose specific values for the parameters. Following the 'calibration approach' advocated by Kydland and Prescott (1982), parameter values are selected on the basis of considerations other than BC ones. Share parameters are selected to match certain long run properties of the data whereas utility parameters are selected from previous econometric studies (Kydland and Prescott (1991b) stress that these parameters should not be chosen to produce the best fit of the model to the data because all models are, by definition, false).

Although this procedure seems quite straightforward, there are two important issues to be noted. The first one concerns the choice of moments to be matched. Some parameters are selected in order to match a particular statistic (i.e, adjustment costs to investment are selected to match the variance of investment in the data). However, in these highly interdependent models it is quite likely that this parameter will affect the complete dynamics of the system, and therefore should be selected using the whole set of first order conditions and not just a subset of it. The second one concerns the absence of standard errors associated to the parameter values.

Singleton (1988) addressed these concerns and pointed out that the calibration procedure should be formally treated as a method of moments estimation problem (see Christiano and Eichembaum (1992) for an application of this GMM procedure to a RBC model). However, this solution is not free of problems. Mao (1988) has found that the GMM estimator is strongly biased in small samples whereas Canova et al. (1994) have found that this bias is even larger when the utility function is logarithmic. Thus, with the standard model and the samples typically available the procedure is likely to obtain poor estimates.

An alternative way of formalizing the calibration procedure is to estimate the models by Maximum Likelihood (see Altug (1988) or McGrattan (1991) among others). This approach linearizes the model around the steady state and estimates the resulting VAR imposing the cross-equation restrictions that arise because the VAR parameters depend on the deep parameters of the model. This approach has its own problems as well: it is not applicable when there are unobserved variables (i.e. productivity) or when the vector of errors is of smaller dimension than the vector of variables.

Finally, Canova (1994b) and Ingram et al. (1994) suggest a Bayesian Calibration procedure which does not assign a point estimate but a density function to each of the parameters that have to be calibrated. This introduces uncertainty in the calibration and permits rigorous statistical analysis of the results.

## Goodness of Fit and Sensitivity Analysis

### Sensitivity analysis

Once the model is calibrated, the researcher wants to carry out computational experiments. If all the parameters could be perfectly calibrated, then one set of experiments would be enough. However, this is not usually the case and some sensitivity analysis to variations of critical parameters within a reasonable range is needed in order to check how conclusions would be modified under alternative parameterizations. This is usually done in an informal way by repeating the experiments with slightly different parameterizations. However, some authors have proposed more formal ways of doing it. Pagan and Shannon (1985) propose the computation of 'sensitivity elasticities', a function that would indicate how a particular statistic depends on the parameter vector. This procedure could be regarded as a form of local sensitivity analysis, because it only analyzes the statistics in a neighborhood of the point estimate. Canova (1994b) proposes a procedure for global sensitivity analysis that consist on drawing the parameters from some density (that would correspond to prior research or conventional wisdom), computing the statistics for each draw and, finally, constructing the density of the statistics.

### Goodness of Fit

The final step is the assessment of the performance of the model. This is generally done by informally comparing simulated data with the actual data and, whenever possible, giving a quantitative assessment of the performance of the model with respect to the question in mind, for example, a numerical estimate of the fraction of output variability that is explained by technology shocks.

Recently, some more formal ways of assessing the goodness of fit of the model and of comparing the performance of two competing models have been developed.

Taking advantage of the fact that RBC models can be expressed in terms of a VAR, Smith

(1993) and Canova et al.(1994) test whether the restrictions that the theoretical model places upon the implicit VAR are valid or not. Whenever the model displays a stochastic trend some cointegrating restrictions can also be tested. King and Watson (1992) and Canova (1993a) propose instead to compare the theoretical and estimated impulse response functions. This procedure does not add any new information with respect to the VAR but is easier to implement and more intuitive in economic terms. An alternative to the above analysis is to reduce the VAR to pairs of interesting variables (see Canova et al (1994)) or compare the univariate ARMA representation of certain variables with that found in data, as advocated by Zellner and Palm (1974) (see Cogley and Nason (1992, 1993) for an application of this procedure to Christiano and Eichembaum (1992) model). The VAR representation allows us also to compare the performance of two alternative models rather than evaluate the performance of a single model, through the use of encompassing techniques (see Hoover (1991) and Canova et al. (1994)).

A different approach to assessing the relation of the model to data is to hold the data fixed and see how likely it is that some statistics of the data could have come from the model (see Gregory and Smith (1991) and Canova (1994b) for a description and Canova and De Niccolo (1995) for an application to the equity premium puzzle).

Finally, using spectral techniques that may circumvent the problem of the presence of errors in variables, Watson (1993) proposes to analyze how much error should be added to the model spectrum to reproduce the spectrum of the data as a proxy for a goodness of fit measure. Diebold et al (1994) take the work of Watson one step further and present a formal framework for comparing the spectral structure of model and data using empirical bootstrap distributions. Ortega (1995) develops a similar procedure by constructing asymptotic tests for comparison of the spectral structure of the model and the data.

## Extensions of the basic model

The basic RBC model presented by Kydland and Prescott (1982) performed surprisingly well in replicating some of the characteristics of the U.S. business cycle, but it was clearly a first step and left several aspects of the data unexplained. Since then, the RBC research program has expanded in many directions which we briefly discuss.

**Labor Markets** Perhaps the sector whose behaviour RBC models find more difficult to replicate is the labor market. There are at least three labor market facts that the standard model is not able to match: in the model, employment is less variable than productivity, and the output-productivity and output-wages correlation and the correlation between hours worked and the return to working are too high. All these problems have led researchers to devote their attention to the solution of these issues, and in doing so the basic model has been extended in many directions. In what follows we review some of the most important developments. Perhaps one of the most interesting modifications of the basic model has been the indivisible labor structure of Hansen (1985). Contrary to the basic model (where all the variation is in hours worked) and supported by the fact that the majority of the variation in labor input in OECD countries is due to changes in the number of employed workers (see Burdett and Wright (1989)), Hansen (1985) assumes that workers can work either a fixed number of hours or not at all. He then convexifies the consumption set by adding lotteries as in Rogerson (1988), and obtains a model in which workers, having consumption completely insured against unemployment, are allocated to jobs randomly. This modification increases the labor supply elasticity and raises the standard deviation of hours above that of productivity.

However, this new feature does not drive down the positive correlation between hours and productivity. This result arises because the presence of a single shock in the model can be interpreted as shifting the labor demand curve along a fixed labor supply curve, producing a strong positive relationship between hours and productivity. The introduction of more sources of shocks, in particular to labor supply, may be a solution to this problem. In fact, Christiano and Eichembaum (1992) present a model with technology and government spending shocks that shift both supply and demand curves and that is able to reduce the correlation.

An alternative way of obtaining the same result and that is becoming increasingly popular to analyze alternative issues (see Baxter and Jeerman (1994) or Perli (1994) among many others) is the introduction of Household Production in the model (see, i.e., Benhabib et al. (1991) or Greenwood et al (1993)). The basic idea is that agents derive utility from home-produced as well as market-produced consumption goods and derive disutility from working at home as well as in the market. This modification adds to the standard intertemporal leisure/market-work substitution the intratemporal home-work/market-work substitution and, by shifting the labor supply curve, it allows the model to replicate the pattern of hours and productivity that we see in the data.

A final issue is related to the existence of labor hoarding. Labor hoarding enables firms to change the effective labor supply without altering unemployment, so reducing the correlation between productivity and measured labor input. Labor hoarding can be introduced into the model by assuming that firms must hire workers before the current state of technology is observed, as a way of eliminating the possibility of costless and infinite adjustments of the workforce in response to any new information. This mechanism will affect the labor supply curve and reduce the positive hours-productivity correlation (see Burnside et al (1990)). An alternative is Kydland and Prescott (1991a), who developed a model that allows for variation in both hours per worker and number of employees, and therefore combines the issues of indivisible labor and labor hoarding.

**Money** A second important extension of the basic model has been the introduction of money. It is well known that the money stock is procyclical (see e.g. Kollintzas and Fiorito (1994)). RBC theory assumes that real disturbances are the only responsibles for output variability, and that policy-induced fluctuations in monetary variables have no effect on real variables. Therefore, some explanation needs to be given for this procyclicality. King and Plosser (1984) explain it with a reverse causation argument: money changes in response to output changes. Their argument is that if financial services can be produced faster than goods, a positive technology shock will raise output and increase the demand for financial services, producing a positive money-output correlation. Many researchers have tried to introduce money in RBC models, primarily in three ways: through transaction technologies (Marshall (1987), through price misperceptions à la Lucas (1972) (see Kydland (1989)) and through a cash-in-advance constraint (Cooley and Hansen (1989)). However, none of these approaches has reached the conclusion that money disturbances have a significant effect on output variability.

It is important to note that all these approaches maintained the Walrasian structure typical of RCB models. Cho and Cooley (1989) incorporated nominal wage rigidities into a model in which agents face a cash-in-advance constraint and nominal wages are set at least one period in advance. In this framework, shocks to money supply change relative wages producing real effects, and the effect on output volatility is increased seventy times with respect to a standard RBC model. This feature also improves the general performance of the model, solving the employment/productivity variability puzzle.

**Government** Another source of fluctuations that can drive the economy is government spending. In RBC models (see, for example, Christiano and Eichembaum (1992), Baxter and King (1993) or Finn (1995) among others) government spending is assumed to follow an exogenous stochastic process, and sometimes is allowed to have some effect on the utility of consumers. The basic outcome is that government spending shocks have little effect on output volatility and, depending on the model structure, they may even reduce the volatility of output (see Finn(1995)). Baxter and King (1993) study the implications of RBC models for fiscal policy and demonstrate that, contrary to previous general equilibrium work on fiscal policy, in a RBC framework both labor and capital respond to government spending shocks. They also find that permanent changes in government spending can have both short and long run effects on output whose multipliers exceed one, although permanent shocks have larger effects than transitory ones.

**Monopolistic Competition** One of the assumptions that has been maintained so far in all the models that we have seen is the perfect competition assumption. However, work by Hall (1988) and Rotemberg and Woodford (1991) among others has documented the presence of substantial markups of price over marginal cost in several industries and countries. This fact has fostered the development of general equilibrium business cycle models with imperfect competition and increasing returns to scale. Recent papers by Rotemberg and Woodford (1992), Horstein (1993), Gali (1994) and many others have studied theoretically and empirically the business cycle implications of monopolistic competition, and found that it helps to replicate important features of the data, in particular those of the labor market.

**International Business Cycles** The last extension that we consider is the development of open economy RBC models. These models have been used primarily to study both the determinants of aggregate fluctuations in open economies and the transmission of idiosyncratic shocks across countries. For example, Mendoza (1991), Correia, Neves and Rebelo (1992) and Lundviik (1991) have addressed the question of what generates aggregate fluctuations in a small open economy. Backus, Kehoe and Kydland (BKK) (1992) have considered a two country-one good model driven by technological shocks to investigate the international propagation of domestic cyclical fluctuations. Others have extended the basic one good framework to include multiple sources of shocks (e.g. government spending (Ravn (1993)), multiple sources of transmission (production and consumption interdependencies (Canova (1993a)), nontradable consumption goods (Stockman and Tesar (1994)) and studied the properties of these models for trade issues (J-curve, see BKK (1993), policy questions (saving and investment correlations, see Baxter and Crucini (1993) or Van Wincoop and Marrinan (1994)) and insurance schemes (see e.g. Deveraux, Gregory and Smith (1992)). There have also been a few attempts to introduce money into these models, see e.g. Cardia (1991). We review these extensions in depth in the next Chapter.

# Chapter 1

# International Business Cycles

One of most active areas of business cycle research in the last few years has been the development of open economy RBC models to analyze the determinants of aggregate fluctuations in open economies and its international transmission. The increasing internationalization of developed economies and the development of highly sophisticated international capital markets has the implication that we can not neglect the foreign sector when we wish to analyze the cyclical fluctuations of developed economies. Countries are assumed to experience imperfectly correlated shocks to their technologies, and the interaction between these shocks and the possibility of international borrowing and lending may have a substantial influence in aggregate fluctuations. These borrowing and lending possibilities allow countries to run trade surpluses or deficits, adding to the closed economy framework a new and interesting way of transmission of shocks.

This literature has its origins in general equilibrium models of international trade by Dellas (1986), Stockman and Svensson (1987) and Cantor and Mark (1988), and was incorporated to the RBC research program by Backus, Kehoe and Kydland (1992) (BKK).

## 1.1 International Stylized Facts

Empirical research on international business cycles has found a great deal of regularity on cyclical fluctuations across countries (see, i.e. Danthine and Girardin (1989), Kydland and Prescott (1990), Backus and Kehoe (1992), Ravn (1993), Christodoulakis et al. (1993) or Fiorito and Kollintzas (1994)).

We review the properties of International Business Cycles in developed economies in the post-war period (summary statistics appear in Tables (1.3) and (1.4)). We do so very briefly because several authors, have extensively documented the features of international business cycles. However, our effort is worthwhile because we use a different and extended data set.

The data are quarterly seasonally adjusted from OECD Main Economic Indicators [1] for

[1] Data for Spain is from INE, Contabilidad Nacional Trimestral, and were kindly supplied by Eva Ortega

Australia, Canada, France, Germany, Italy, Japan, Spain, Switzerland, U.K., U.S. and the aggregate European Community (E.U.) constructed by the OECD, for the period 1970:1 to 1993:4. To isolate the business cycle properties of the data, we follow existing literature and use the Hodrick and Prescott (HP) filter with $\lambda = 1600$. We will focus on second moments of the data: standard deviations are in Table 1.3 and correlations are in Table 1.4. For correlations we present the point estimates and their standard error computed using a Newey and West procedure.

Consumption, employment, productivity (measured as the Solow Residual) and net exports are less volatile than output while investment, exports, imports and terms of trade are more volatile. The percentage standard deviation of output ranges from 1.03 for France to 1.92 for Switzerland. The relative standard deviation of consumption goes from 0.64 for Australia to 1.17 for the U.K., while employment varies a bit more across countries, probably because of the different labor market structures, with values ranging from 0.53 for France to 1.11 for Spain. The variability of productivity relative to output ranges from 0.76 for Switzerland to 1.08 for Spain. Hence, we need more than productivity variability in order to fully explain cyclical fluctuations in output.

All domestic variables are procyclical with respect to output with the exception of the ratio of net exports to output, which is countercyclical in all countries, and of the terms of trade. Basic saving, constructed as $S_t=Y_t-C_t-G_t$, and investment are positively correlated in every country and the correlation is higher for larger countries and ranges from 0.1 for France to 1.0 for Europe as a whole. In all cases the correlation is significatively different from zero at the 5% confidence level. The behavior of net exports is less clear since it is negatively correlated with output in the U.S. but, in general, positively correlated in other countries.

An important issue discussed in the literature is the existence of the so-called "J-curve", a situation in which a deterioration in the terms of trade is associated with an initial worsening of the trade balance and a subsequent improvement. The evidence on this issue is quite contradictory and, despite the great deal of attention received from both policy makers and academic economists, recent studies, such as Rose and Yellen (1989), have found very little evidence of a stable J-curve in post-war U.S. data. However, BKK(1993) argue that the appropriate relationship to be examined is not the J-curve but the "S-curve". This S-curve describes the correlation between the terms of trade and the balance of trade at different lags and leads. Figure 1.1 shows this picture for eight OECD countries. The general pattern is that the contemporaneous and lagged correlation between the terms of trade and lagged net exports is negative but the correlation between the terms of trade and future net exports is positive. It should be clear that the "S-curve" is a description of the unconditional cross-correlation between two variables whereas the "J-curve" is the conditional dynamic response of one variable to a shock in another, and therefore it is perfectly possible to find a "S-curve" in the data but not a "J-curve".

International comovements indicate that output is more correlated across countries than productivity. The ranges of output correlations and productivity correlations are [0.16, 0.76] and [0.10, 0.67] with mean values of about 0.48 and 0.32, respectively. Hence, just as variation in the Solow residuals is not enough to explain domestic output fluctuations, it is also not enough to account for international output comovements. A second important regularity of international data is the low cross country consumption correlation. For the countries in the panel the range is between -0.14 and 0.69 and the mean value is about 0.29 and such correlations are, in general, lower than the corresponding output correlations. Investment and employment also display positive comovements across countries (the ranges are [-0.01, 0.77], [0.09,0.77] respectively), and the same occurs for imports and exports (ranges [0.06, 0.91] and [0.08, 0.89]). Government spending displays low cross-country correlations, a fact that may indicate the lack of fiscal policy coordination across countries.

Among the countries of the panel, the strongest correlations for all countries appear, as expected, between the US and Canada and among the EEC countries; also, Spain seems to show a slightly different behavior.

## 1.2 A prototypical IBC model

### 1.2.1 The Model

In this section we present a basic international business cycle model, in the spirit of BKK(1992). There are two countries in this economy and a single final good is produced. We assume that the countries are so small that they cannot individually affect the determination of equilibrium in the rest of the world. Countries are populated by a large number of utility maximizers infinitely-lived identical agents. The household sells the services of capital and labor, owns all the firms and receives all the profits. The goods produced by the firms will be purchased by the household in order to be consumed or invested. There are complete financial markets within countries and free mobility of physical and financial capital across countries. However, labor is immobile internationally. Each household in country $h$ has preferences given by the utility function

$$U_{ht} = E_t \left[ \sum_{i=0}^{\infty} \beta^i u(C_{ht+i}, L_{ht+i}) \right] \tag{1.1}$$

where $C_{ht}$ is consumption at time t and $L_{ht}$ is leisure. The endowment of time is $H_t$ in each period, which constrains leisure to be between 0 and $H_t$.

The instantaneous utility function, $u(.)$, is generally of the CRRA type in order to ensure that trend growth in wages does not lead to trend growth in leisure (see the discussion in KPR (1988a))

$$u(C,L) = (1-\sigma)^{-1}(C_t^{\theta} L_t^{1-\theta})^{1-\sigma} \qquad if \sigma \neq 1 \tag{1.2}$$

$$u(C,L) = \theta \ln C_t + (1-\theta) \ln L_t \qquad if \sigma = 1 \tag{1.3}$$

where $0 < \theta < 1$ is the relative weight of consumption to leisure and $\sigma$ is the risk aversion parameter.

There is a representative firm operating in each country that produces output with a constant-returns-to-scale production function

$$Y_{ht} = A_{ht} K_{ht}^{\alpha} (x_{ht} N_{ht})^{1-\alpha} \tag{1.4}$$

where $K_{ht}$ and $N_{ht}$ are capital and labor used by firms in country $h$ and $\alpha$ is a share parameter. $x_{ht}$ represents the state of technology at time t, and in particular an exogenous labor augmenting Hicks neutral deterministic technological progress. Production is subject to a stationary technological shock $A_{ht}$.

Firms accumulate capital goods according to the law of motion

$$K_{h,t+1} = (1-\delta)K_{ht} + I_{ht} \tag{1.5}$$

where $K_{ht}$ is total stock of capital in country $h$, $0 < \delta_h < 1$ is the rate of depreciation of capital stock and $I_{ht}$ is total investment in country $h$.

In addition to consumers and producers, each country is endowed with a government. The government consumes domestic goods ($G_{ht}$), taxes national output with a distortionary tax ($\tau_{th}$) and transfers back the remaining to domestic residents ($T_{ht}$). Alternatively, the government can issue debt that will be repaid by increases in lump-sum taxes or decreases in transfers. The infinite horizon of this economy makes Ricardian equivalence hold: financing current government expenditure with taxes or with debt that will be compensated in the future with either more taxes or less transfers will be equivalent. The government flow budget constraint is given by

$$G_{ht} = T_{ht} + \tau_{ht} Y_{ht} \tag{1.6}$$

which has to hold on a period by period basis. To allow for balanced growth, we will assume that both government spending, taxes and transfers grow along with $x_{ht}$.

There is frictionless international trade in goods, and capital markets are complete, which implies that individuals in this economy can achieve both consumption smoothing (intertemporal transfer of consumption goods) and risk pooling (transfer of consumption goods across states of nature). There is a world resource constraint for the single produced good

$$\Pi_1(C_{1t} + I_{1t} + G_{1t}) + \Pi_2(C_{2t} + I_{2t} + G_{2t}) = \Pi_1 Y_{1t} + \Pi_2 Y_{2t} \tag{1.7}$$

where $\Pi_h$ represent the population of each country. Finally, the trade balance, or net exports, in country $h$ is then given by $NX_{ht} = Y_{ht} - (C_{ht} + I_{ht} + G_{ht})$.

### 1.2.2 Calibration

We parameterize the model following BKK(1992). The parameter values we use are standard in the literature; see their paper for a more detailed explanation. Parameter values appear in Table (1.1). Under this parameterization, the representative agent's discount factor, $\beta$, is 0.99; the coefficient of relative risk aversion, $\sigma$, is 2; the consumption share, $\theta$, is 0.34, which corresponds to a steady state allocation of 30% of discretionary time to market activities. On the production side of the economy, the share of capital, $\alpha$, is 0.36 and the quarterly depreciation rate, $\delta$, is 0.025%.

A crucial element of these models is the measurement and estimation of the exogenous shocks to total factor productivity, proxied by the 'Solow residuals'. It is well known that such a proxy may be very poor since Solow residuals tend to capture factors other than productivity (see e.g. Evans (1992)).

Solow residuals are defined as follows:

$$\ln A_{ht} = \ln Y_{ht} - \alpha \ln K_{ht} - (1-\alpha)\ln N_{ht} \tag{1.8}$$

A typical representation of the joint process for the Solow residuals is

$$\begin{bmatrix} \ln A_{1t} \\ \ln A_{2t} \end{bmatrix} = \begin{bmatrix} \rho_{A1} & \nu_{12} \\ \nu_{21} & \rho_{A2} \end{bmatrix} \begin{bmatrix} \ln A_{1t-1} \\ \ln A_{2t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{bmatrix} \tag{1.9}$$

where $\rho_{Ah}$ is the parameter that governs the persistence of the technology process within country h and $\nu$ is the spillover parameter, that determines the speed at which innovations originating in one country are transmitted to the other. The innovations to the productivity process are given by

$$\epsilon_t \sim N\left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma^2_{\epsilon 1} & \psi_{12} \\ \psi_{21} & \sigma^2_{\epsilon 2} \end{pmatrix} \right) \tag{1.10}$$

It is well known that this proxy measure of productivity has problems due to difficulties in consistently measuring inputs across countries. First, since quarterly series on capital stock are not available in many countries, Solow residuals are calculated using labor as the only input in the production function. Backus, Kehoe and Kydland (1993) have argued that this omission is not important since the capital stock contributes very little to cyclical fluctuations in output. However, recent work by Costello (1993) and Reynolds (1993) shows that the covariance properties of the Solow residuals may be highly sensitive to the measure of capital input. Second, in constructing Solow residuals we assume a constant labor share across countries. Barnard and Jones (1994) have argued that assuming a constant labor share across countries may induce a mismeasurement of productivity growth. While there are differences, the range for OECD countries is not too large (from 0.55 to 0.70) so that the mismeasurement problem seems minor. Finally, labor input is generally measured as the number of people employed rather than total hours worked. Burdett and Wright (1989) showed that this switch may cause distortions, especially for European countries since variation in hours explains more of the variation in total labor than variation in bodies. Zimmermann (1994) finds that the way labor input is measured is important to determine the size of the volatility of simulated output.

Acknowledging these problems, BKK(1992), Ravn (1993) and Reynolds(1993) have constructed several measures of aggregate Solow residuals for different measures of production factors and selected pairs of countries. They all obtain values of persistence very close to one and positive correlations across countries. In addition, both BKK(1992) and Ravn (1993) find evidence of significant spillovers, in particular from the U.S. to other countries, although Reynolds (1993) suggest that these spillovers may be quite low. We will use BKK (1992) estimates, which appear in Table (1.1). The persistence parameter, $\rho_A$, is 0.906, the spillover parameter, $\nu$, is 0.088, the standard deviation is 0.00852 and the cross-country correlation is 0.258.

Government expenditure $G_t = [G_{1t}G_{2t}]$ is assumed to be an autoregressive stochastic process of the form

$$\ln G_t = \rho_g \ln G_{t-1} + \epsilon_{gt} \tag{1.11}$$

where $\rho_g$ is diagonal (there are no spillover effect from government spending) and $\epsilon_{gt}$ is distributed normally with mean zero and diagonal variance-covariance matrix (government spending shocks are uncorrelated). In order to isolate the effects of technology shocks, we set $G_t = 0, \forall t$ for the moment.

### 1.2.3 Simulation results

With this parameterization, the properties of the theoretical economy are described in the column labeled "One Good" in Table (1.2). We can see that, compared with the actual data of Tables 1.3 and 1.4, output, consumption, labor and productivity do not fluctuate enough. On the other hand, the volatility of investment is exaggeratedly high, almost four times larger than in the data. Regarding domestic comovements, labor is too correlated with data whereas investment is not correlated enough and net exports are uncorrelated with output instead of being negatively correlated. International comovements display high cross-country consumption correlations. However, investment, employment and output are negatively correlated across countries in the model but positively in data. It is also important to note that, contrary to empirical evidence, cross-country output correlations are smaller than both productivity and consumption correlations. The intuition behind these results is as follows. Productivity shocks increase the marginal product of capital and stimulate investment and output in the home country. The international transfer of capital goods creates a boom in the home country and a recession in the foreign country, generating negative comovements among real variables. However, because of consumption smoothing and of risk pooling, consumption in both countries move together. Therefore, the crucial properties of this model are that investment drives the cycle and that resources are freely shifted to the more productive location due to the framework of perfect substitutable goods and trade in complete markets for state-contingent claims. Modifications and improvements of the model are thus directed to these properties.

### 1.2.4 Modifications of the basic model

In order to limit trade in physical capital, BKK (1992) include transportation costs in the form of a quadratic cost on goods shipped between countries. With a transport cost of 1 % they lower the volatility of investment by a factor of almost four.

Baxter and Crucini (1993) introduce adjustment costs in the investment process in order to avoid the 'wild' behaviour of investment that appears when capital can freely move across countries. They specify a capital accumulation equation of the form

$$K_{h,t+1} = (1-\delta)K_{ht} + \phi(I_{ht}/K_{ht})K_{ht} \tag{1.12}$$

where the function $\phi > 0, \phi' \geq 0$ and $\phi'' \leq 0$, controls the number of units of output that must be foregone to increase the capital stock in a particular location by a unit. Therefore, $1/\phi'$ can be understood as Tobin's $q$. With this specification it is possible to obtain realistic volatilities of imports and net exports together with high levels of saving-investment correlation.

Baxter and Crucini (1992) alter the perfect capital markets structure by restricting the set of securities to a risk-free non-contingent one-period real bond, so that agents can achieve consumption smoothing but not risk pooling. Let $B_{ht}$ be the per capita quantity of real bonds purchased by country h, $r_t$ the world rate of return on this bonds and $P_t^B = (1+r_t)^{-1}$ the price of a discount bond purchased in period t. In this incomplete markets economy, the world budget constraint (equation (1.7)) is substituted by

$$P_t^B B_{ht+1} + C_{ht} + I_{ht} = Y_{ht} + B_{ht} \tag{1.13}$$

for each of the countries and the market clearing condition in the bonds market is

$$\Pi_1 B_{1t} + \Pi_2 B_{2t} = 0 \tag{1.14}$$

They find that if the productivity process is trend stationary the incompleteness of capital market is not important for the results. However, if technology shocks follow a random walk market completeness matters. Market structure has also been found to be important for the international transmission of fiscal shocks (see Baxter (1992)). Government spending shocks lead to identical responses in both the home and foreign country if markets are complete, because this shock acts as a negative wealth shock which will be shared equally by both countries. However, if capital markets are restricted, the effect of the shock is borne almost completely by the home country, and the effects are completely different. Baxter (1992) and Kollman (1992) have studied with this type of model the twin deficits problem: a situation recently suffered by the U.S. in which internal and external deficits were suffered simultaneously. They both find that this model is able to replicate the data, because an increase in government spending increases investment and therefore imports of capital goods, deteriorating the balance of trade, the result being robust to different market structures.

Technology shocks do not only increase the marginal product of capital but also increase world interest rates, and this effect is stronger the larger is the country suffering the technology shock. Therefore, investment and net exports should be more volatile in small countries, because they can import more capital without affecting interest rates and have a greater share of imports. With different model specifications, Crucini (1992), Head (1992), Zimmermann (1991) and Baxter and Crucini (1993) have analyzed the importance of country size for international business cycles. They all find that country size is significant in explaining the size of the volatility of output and the saving-investment correlation.

A puzzling characteristic of the standard one-good model is the prediction of very high cross-country consumption correlations that are greater than the respective output correlations. This is at odds with the data (see Canova and Ravn (1993) for empirical evidence on OECD countries), and researchers have not been able to resolve this issue in a consistent way. Baxter and Crucini (1992) obtain realistic consumption correlations in their incomplete markets model, but this result is not robust to the presence of spillovers in the technology process. Deveraux, Gregory and Smith (1992) obtain this result with a non additively separable utility function that, however, is not consistent with balanced growth, and Reynolds (1992), although claiming to obtain results able to replicate this stylized fact, presents point estimates of output correlations that are in general lower than the corresponding consumption correlation. Finally, Marrinan (1995) is able to obtain realistic cross-country consumption correlations in a model with government in the utility function, but in order to do so she needs to impose an effect (0.8) of government expenditure in consumers' utility that is too large compared to that found in the data (0.2, see Ashauer (1985)).

Thus, the one good model, although providing the basic intuition behind the dynamics of international business cycles, leaves many questions open, and has nothing to say about imports, exports and the terms of trade (the terms of trade are obviously equal to one in this economy).

## 1.3 A Multiple Goods Model

A natural extension of the model, that allows us to analyze the behaviour of imports, exports and the terms of trade and eliminates substitutability between goods, is one where each country specializes in the production of a single differentiated good. This implies that we can distinguish goods by industrial category and by country of origin and therefore consider goods from the same industrial category but from different country of origin as different goods. This specification prevents the model from also generating wild capital movements in the absence of adjustment costs and allows for consumption and/or production interdependences.

One way of introducing multiple goods in the model is to assume as in BKK (1993) that $Y_{ht}$ can be either used domestically or exported

$$Y_{1t} = A_{1t} + \frac{\Pi_2}{\Pi_1}\tilde{A}_{2t} \tag{1.15}$$

$$Y_{2t} = B_{1t} + \frac{\Pi_1}{\Pi_2}\tilde{B}_{2t} \tag{1.16}$$

where $\tilde{A}_{2t}$ and $B_{1t}$ are exports and imports of country 1. We let $A_{2t}=\frac{\Pi_2}{\Pi_1}\tilde{A}_{2t}$ and $B_{2t}=\frac{\Pi_1}{\Pi_2}\tilde{B}_{2t}$. Imports and domestic market goods are then used in the production of a final domestic market good in each country, $V_{ht}$, according to a CES technology of the form (see Armington (1969)):

$$V_{1t} = (\varpi_1 A_{1t}^{1-\rho} + \varpi_2 B_{1t}^{1-\rho})^{\frac{1}{1-\rho}} \tag{1.17}$$

$$V_{2t} = (\varpi_1 B_{2t}^{1-\rho} + \varpi_2 A_{2t}^{1-\rho})^{\frac{1}{1-\rho}} \tag{1.18}$$

where $1/\rho$ is the elasticity of substitution between domestic and foreign goods and $\varpi_1$ and $\varpi_2$ are parameters regulating the domestic and foreign content of GNP. This is a very convenient specification because it allows for cross-hauling (a situation in which a country imports and exports goods of the same category) and permits both countries to produce the same categories of goods [2].

The relative price of imports to exports (terms of trade) is given by:

$$P_{1t} = \frac{\partial V_1/\partial B_{1t}}{\partial V_1/\partial A_{1t}} = \frac{\varpi_2 B_{1t}^{-\rho}}{\varpi_1 A_{1t}^{-\rho}} \tag{1.19}$$

where $\varpi_1 = (1 - MS)^{\rho}$, $\varpi_2 = MS^{\rho}$ and where $MS$ is the import share in output.

Now, the aggregate resources constraint for the traded goods in the world economy becomes

$$\Pi_1 V_{1t} + \Pi_2 V_{2t} = \Pi_1(C_{1t} + I_{1t} + G_{1t}) + \Pi_2(C_{2t} + I_{2t} + G_{2t}) \tag{1.20}$$

We have to calibrate only two more parameters relative to the one good model, the steady state import share, $MS$, and the parameter governing the elasticity of substitution in the Armington aggregator, $\rho$. Following BKK(1993) we set $MS$=0.15 and $\rho$=1.5.

### Simulation Results

The multiple goods model improves the behaviour of the single good model along several lines. The presence of multiple goods makes net exports countercyclical, and this is so because imports

[2] An alternative specification would be to distinguish goods not by industrial category but by the firm that produces the good (see, i.e., Dixit and Stiglitz (1977)), but this would need the introduction of imperfectly competitive firms.

are more procyclical than exports. However, since imports are primarily composed of capital goods, imports are too procyclical as is investment.

The imperfect substitution between goods rises the cross-country output correlation, although it is still too low. It also has the implication that now the volatility of investment is realistic without the need of any adjustment or transportation costs.

The model generates both an S-curve and a J-curve; because a positive technology shock leads to a deterioration of the terms of trade, mainly due to imports of capital. As the shock is transmitted and the investment boom slows down the trade balance improves. Clearly, these properties are a consequence of the dynamics of capital accumulation.

The model is also able to replicate the negative Terms of trade-Net exports correlation that it is found in the data (except for the U.S.). However, it badly fails to replicate the variability of the terms of trade and this result is robust to reasonably alternative parameterizations (see BKK(1993) for an exhaustive analysis).

Thus, the multiple good model works well along many dimensions but there are still at least four aspects of the data which are mismatched. First, output, consumption, hours, and in particular terms of trade, imports and exports do not fluctuate enough (volatility-foreign trade puzzle). Second, hours, investment and imports are too highly correlated with output while the correlation between exports and output is too small (procyclicality puzzle). Third, consumption is more correlated than output across countries (risk sharing puzzle). Fourth, investment, hours, imports and exports are either negatively correlated or show no correlation across countries (comovement puzzle).

In order to solve these four puzzles, the model has been extended and modified in several ways.

## 1.4 Extensions

### Risk Sharing

Restricting capital markets is again the most intuitive way of solving this puzzle. Arvanitis and Mikkola (1994) find that restricting asset trade to noncontingent real bonds helps to resolve the risk sharing puzzle if the productivity shocks are persistent enough, although they can not solve the comovement puzzle.

The introduction of nontraded goods in the model can, in principle, lower the cross-country consumption correlations, because the nontraded components of consumption are not connected across countries. Among others, Backus and Smith (1992), Reynolds (1992), Tesar (1992) or Zimmermann (1991) have introduced non-traded goods into their models. Stockman and Tesar (1994) devise a model of this type in which the utility function is not separable between traded and nontraded consumption goods. Their result is that now traded goods consumption, instead of total consumption, is more correlated across countries than output.

An alternative to the explicit modelling of a non-traded sector is the approach of Ravn(1993) and Canova (1993a), who introduce the government in the model and allow it to affect the utility of consumers, acting therefore as a nontraded good. They find that the cross-country consumption correlation is negatively related to the degree at which government spending affects the utility of consumers.

Finally, Stockman and Tesar (1994) introduce also in the model shocks to preferences. They add a shock to the first order condition that links consumption and prices, and this fact is able to reduce the correlation of both total and trade goods consumption across countries. However, this has the drawback that these shocks are neither quantifiable nor observable.

## Foreign Trade

Another issue that the model fails to explain is the behavior of foreign trade variables. Advances in this area have gone from relating imports and exports to the industrial structure of the economy to explicitly modelling the terms of trade.

For example, Kouparsitas(1994a,b) finds that the volatility of both net exports and the terms of trade is linked to the industrial structure of the economy, and in particular to the composition of imports and exports. Arvanitis and Mikkola (1994) experiment with different international elasticities of substitution in consumption and in production, with the intuition that both a low elasticity in consumption and a high elasticity in production can raise the volatility of the terms of trade. This change does amplify the volatility of the terms of trade, but not enough to match the data.

Regarding the modelling of the terms of trade, the innovations have been either to introduce money in the model or to explicitly model the terms of trade. Grilli and Rubini (1992) and Schlagenhauf and Wrase (1992) have both adapted Lucas's (1990) liquidity model to the open economy. In this framework, asset and goods markets are separated by one period and therefore shocks to the money supply have one-period effects on interest rates, relative prices and exchange rates. However, these effects are not as persistent as they are in the real world.

The alternative to this approach is to model persistent exchange rate shocks. For example, Mendoza(1992) develops a three-good model of a small open economy facing a fixed world interest rate, and finds that, in a model calibrated to G7 countries, terms of trade shocks can account for half of observed output variability. Zimmermann(1994b) develops a three country model with technology and exchange rate shocks, calibrated to three economic areas, Europe, North America and Japan. He is able to improve somewhat the behaviour of the terms of trade generated by the model, although his results are very sensitive to some crucial parameters.

## International Comovements

The final unsolved issue regards international comovements. It seems clear that a model driven by a single source of variability is quite likely to generate negative international comovements.

A way out of this puzzle may be the introduction of more shocks (for example, government spending or preference shocks) or, perhaps more interestingly, increase the interdepences of these economies. For example, Canova (1993a) develops a three good, three country model in which each country specializes in the production of one good and where there are both consumption and production interdependences. In other words, consumers enjoy the consumption of domestic and foreign goods and domestic and foreign capital is used in the production of domestic goods. He analyzes the impulse responses of a version of the model parameterized to the U.S., Germany and Japan. He finds that production interdependences determine the propagation of technology shocks whereas consumption interdependences determine the transmission of government shocks. Although he did not report standard statistics and therefore we do not know whether this modification solves the puzzle, it seems an interesting way to proceed.

### Applications

Finally, it is interesting to see what type of questions these models want to address. In general, these models ask questions of the type: How much variability of output can be explained by technology shocks? This simple question has been recently extended and could be put in the following way: Can we reproduce the overall macroeconomic behaviour of OECD economies? This means that researchers are developing models that are able to replicate the main stylized facts of International Business Cycles. Once we have models that can be considered a good representation of reality, we can proceed and utilize them for applied analysis. This is for example the case of Canova(1993a), who asks whether there are common shocks or transmission of shocks among G-3 countries, the so-called "locomotive effects". Along the same lines, Costello and Praschink (1993) study the interrelationships of macroeconomic aggregates across industrialized and developed countries. They found that output in the U.S. and Japan Granger-causes output in developed countries and has a sizable influence in their business cycle. Kouparsitas(1994c) constructs a two-region world, in which the "North" imports raw materials and exports manufactured goods and the "South" exports raw materials and imports manufactured goods. Calibrating the North to OECD economies and the South to non-oil developing countries, this framework is used to examine to which extent fluctuations in the North are responsible for fluctuations in the South. Finally, Kehoe and Kehoe (1994) use these models to analyze the welfare effects of the NAFTA agreement in the participating countries.

Table 1.1: Parameter Values

| | | | | |
|---|---|---|---|---|
| Preferences | $\beta = 0.99$ | $\theta = 0.34$ | $\gamma = 2$ | |
| Technology | $\alpha = 0.36$ | $\delta = 0.025$ | $1/\rho = 1.5$ | MS=0.15 |
| Forcing Processes | $\begin{bmatrix} \rho_{A1} & \nu_{12} \\ \nu_{21} & \rho_{A2} \end{bmatrix}$ | = | $\begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}$ | |
| | $\sigma^2_{e1} = \sigma^2_{e2} = 0.00852^2$ | | $\psi_{21} = \psi_{12} = 0.258$ | |

Table 1.2: Simulation results

| | One Good | Two goods |
|---|---|---|
| STD(Y) | 1.50 | 1.38 |
| AR1(Y) | 0.62 | 0.63 |
| STD(C) | 0.42 | 0.47 |
| STD(N) | 0.50 | 0.42 |
| STD(I) | 10.99 | 3.48 |
| STD(AP) | 0.67 | 0.75 |
| STD(NX) | 3.77 | 0.30 |
| STD(TOT) | | 0.48 |
| CORR(C,Y) | 0.77 | 0.88 |
| CORR(N,Y) | 0.93 | 0.94 |
| CORR(I,Y) | 0.27 | 0.93 |
| CORR(AP,Y) | 0.89 | 0.99 |
| CORR(NX,Y) | 0.01 | -0.64 |
| CORR(X,Y) | | 0.24 |
| CORR(M,Y) | | 0.98 |
| CORR(TOT,Y) | | 0.49 |
| CORR(TOT,NX) | | -0.41 |
| CORR(Y,Y*) | -0.21 | 0.02 |
| CORR(C,C*) | 0.88 | 0.77 |
| CORR(I,I*) | -0.94 | -0.58 |
| CORR(N,N*) | -0.78 | -0.54 |
| CORR(AP,AP*) | 0.25 | 0.24 |
| CORR(X,X*) | | -0.01 |
| CORR(M,M*) | | -0.23 |

Note: The variables are: Y, real output, C, real private consumption, N, employment, I, real total investment, X, real exports, M, real imports, NX, ratio of real net exports to real output, AP is average productivity, TOT, ratio of implicit price deflator to that of imports. Data is Hodrick-Prescott filtered and in logs.

Table 1.3: Domestic Moments

1.3.A.- Domestic Standard Deviations

| | Absolute | | Relative to Y | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Country** | **Y** | **NX** | **C** | **I** | **HM** | **X** | **M** | **AP** | **TOT** |
| Australia | 1.61 | 1.16 | 0.64 | 2.79 | 0.79 | 3.35 | 4.41 | 0.85 | 5.79 |
| Canada | 1.61 | 0.75 | 0.86 | 2.86 | 0.88 | 3.28 | 3.79 | 1.01 | 2.82 |
| France | 1.03 | 0.81 | 0.81 | 3.05 | 0.53 | 4.33 | 6.17 | 0.81 | 3.33 |
| Germany | 1.46 | 0.69 | 0.75 | 2.81 | 0.75 | 3.08 | 3.20 | 0.89 | 3.13 |
| Italy | 1.60 | 1.01 | 0.87 | 2.54 | 0.84 | 2.92 | 4.78 | 0.99 | 3.50 |
| Japan | 1.72 | 0.91 | 0.71 | 2.26 | 0.95 | 4.76 | 7.84 | 0.98 | 7.37 |
| Spain | 1.14 | 0.97 | 1.05 | 4.49 | 1.14 | 2.83 | 4.22 | 1.08 | N.A. |
| Switzerland | 1.92 | 1.27 | 0.67 | 3.02 | 1.03 | 2.00 | 3.32 | 0.76 | 2.69 |
| U.K. | 1.74 | 1.18 | 1.17 | 2.91 | 0.80 | 3.05 | 4.33 | 0.84 | 3.09 |
| U.S. | 1.75 | 0.50 | 0.75 | 3.32 | 0.93 | 3.78 | 3.29 | 0.78 | 3.32 |
| E.U. | 1.54 | 0.48 | 0.73 | 2.21 | 0.55 | 2.41 | 3.08 | 0.89 | N.A. |

1.3.B.- Domestic Correlations

| Country | (C,Y) | (I,Y) | (HM,Y) | (X,Y) | (M,Y) | (NX,Y) | (TOT,Y) | (S,I) | (TOT,NX |
|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.42 | 0.66 | 0.53 | 0.36 | 0.34 | -0.09 | -0.41 | 0.48 | -0.01 |
| | (0.06) | (0.07) | (0.10) | (0.06) | (0.06) | (0.66) | (0.08) | (0.07) | (0.05) |
| Canada | 0.72 | 0.69 | 0.36 | 0.71 | 0.75 | -0.21 | -0.13 | 0.26 | -0.02 |
| | (0.05) | (0.04) | (0.08) | (0.05) | (0.03) | (0.09) | (0.01) | (0.10) | (0.03) |
| France | 0.64 | 0.80 | 0.68 | 0.47 | 0.53 | -0.33 | -0.03 | 0.10 | -0.49 |
| | (0.04) | (0.10) | (0.10) | (0.09) | (0.08) | (0.10) | (0.09) | (0.10) | (0.03) |
| Germany | 0.73 | 0.84 | 0.47 | 0.33 | 0.38 | -0.08 | -0.39 | 0.97 | 0.09 |
| | (0.01) | (0.09) | (0.06) | (0.10) | (0.09) | (0.10) | (0.02) | (0.07) | (0.05) |
| Italy | 0.68 | 0.79 | 0.28 | 0.30 | 0.67 | -0.61 | 0.34 | 0.97 | -0.59 |
| | (0.08) | (0.10) | (0.06) | (0.07) | (0.05) | (0.04) | (0.02) | (0.07) | (0.01) |
| Japan | 0.64 | 0.71 | 0.16 | 0.04 | 0.18 | -0.23 | -0.06 | 0.87 | -0.54 |
| | (0.01) | (0.10) | (0.07) | (0.08) | (0.07) | (0.06) | (0.08) | (0.08) | (0.07) |
| Spain | 0.73 | 0.78 | 0.66 | 0.16 | 0.65 | -0.44 | N.A. | 0.75 | N.A. |
| | (0.02) | (0.08) | (0.07) | (0.04) | (0.11) | (0.10) | (0.00) | (0.09) | (0.00) |
| Switzerland | 0.80 | 0.84 | 0.65 | 0.60 | 0.79 | -0.71 | 0.43 | 0.61 | -0.58 |
| | (0.01) | (0.05) | (0.11) | (0.09) | (0.03) | (0.02) | (0.07) | (0.07) | (0.07) |
| U.K. | 0.85 | 0.73 | 0.55 | 0.35 | 0.43 | -0.28 | 0.15 | 0.70 | -0.56 |
| | (0.07) | (0.10) | (0.08) | (0.09) | (0.07) | (0.08) | (0.05) | (0.10) | (0.04) |
| U.S. | 0.88 | 0.93 | 0.63 | 0.09 | 0.55 | -0.48 | -0.21 | 0.40 | 0.17 |
| | (0.06) | (0.05) | (0.02) | (0.11) | (0.05) | (0.06) | (0.02) | (0.11) | (0.09) |
| E.U. | 0.93 | 0.87 | 0.46 | 0.23 | 0.24 | -0.18 | N.A. | 1.00 | N.A. |
| | (0.05) | (0.09) | (0.09) | (0.13) | (0.13) | (0.12) | (0.00) | (0.07) | (0.00) |

Notes: The data is quarterly and from OECD's Quarterly National Accounts, except for employment which is from OECD Main Economic Indicators, and for Spain which is from INE Contabilidad Nacional Trimestral. The sample period is 1970:1 to 1993:4. Data is Hodrick-Prescott filtered and in logs except for the ratio of net exports to output. The variables are: Y, real output; C, real private consumption; HM, civilian employment; I, real fixed investment; S, domestic saving; X, real exports; M, real imports; NX, ratio of real net exports to real output; AP is productivity measured as the Solow residuals; TOT, ratio of implicit price deflator of imports over that of exports. Standard errors computed using a Newey and West procedure are in parenthesis.

Table 1.4: Cross-country Correlations

1.4.A.- Output correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.62 | 0.37 | 0.39 | 0.42 | 0.34 | 0.37 | 0.23 | 0.30 | 0.47 | 0.40 |
| | (0.03) | (0.08) | (0.07) | (0.08) | (0.07) | (0.08) | (0.13) | (0.07) | (0.06) | (0.07) |
| Can | | 0.26 | 0.34 | 0.44 | 0.16 | 0.36 | 0.33 | 0.53 | 0.76 | 0.44 |
| | | (0.08) | (0.06) | (0.07) | (0.08) | (0.08) | (0.11) | (0.06) | (0.06) | (0.06) |
| Fra | | | 0.65 | 0.65 | 0.58 | 0.67 | 0.59 | 0.49 | 0.36 | 0.77 |
| | | | (0.04) | (0.06) | (0.05) | (0.08) | (0.12) | (0.03) | (0.04) | (0.04) |
| Ger | | | | 0.59 | 0.58 | 0.56 | 0.29 | 0.38 | 0.57 | 0.76 |
| | | | | (0.06) | (0.06) | (0.08) | (0.12) | (0.07) | (0.04) | (0.06) |
| Ita | | | | | 0.34 | 0.67 | 0.48 | 0.34 | 0.37 | 0.62 |
| | | | | | (0.06) | (0.07) | (0.07) | (0.15) | (0.06) | (0.07) |
| Jap | | | | | | 0.42 | 0.34 | 0.25 | 0.36 | 0.61 |
| | | | | | | (0.04) | (0.02) | (0.05) | (0.01) | (0.03) |
| Swi | | | | | | | 0.52 | 0.27 | 0.35 | 0.65 |
| | | | | | | | (0.04) | (0.05) | (0.04) | (0.06) |
| Spa | | | | | | | | 0.36 | 0.47 | 0.67 |
| | | | | | | | | (0.08) | (0.11) | (0.02) |
| U.K. | | | | | | | | | 0.62 | 0.68 |
| | | | | | | | | | (0.06) | (0.03) |
| U.S. | | | | | | | | | | 0.62 |
| | | | | | | | | | | (0.04) |

1.4.B.- Consumption correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.33 | 0.01 | -0.02 | 0.12 | -0.14 | -0.03 | -0.13 | -0.02 | 0.12 | -0.03 |
| | (0.05) | (0.03) | (0.03) | (0.03) | (0.03) | (0.09) | (0.03) | (0.03) | (0.04) | (0.03) |
| Can | | 0.34 | 0.24 | 0.31 | 0.07 | 0.34 | 0.24 | 0.30 | 0.69 | 0.37 |
| | | (0.05) | (0.10) | (0.10) | (0.10) | (0.13) | (0.10) | (0.08) | (0.07) | (0.08) |
| Fra | | | 0.30 | 0.27 | 0.25 | 0.26 | 0.30 | 0.17 | 0.38 | 0.37 |
| | | | (0.01) | (0.01) | (0.01) | (0.00) | (0.12) | (0.01) | (0.00) | (0.01) |
| Ger | | | | 0.21 | 0.49 | 0.36 | 0.16 | 0.35 | 0.25 | 0.37 |
| | | | | (0.09) | (0.08) | (0.09) | (0.14) | (0.09) | (0.08) | (0.09) |
| Ita | | | | | 0.10 | 0.55 | 0.54 | 0.23 | 0.13 | 0.44 |
| | | | | | (0.05) | (0.05) | (0.14) | (0.05) | (0.05) | (0.06) |
| Jap | | | | | | 0.09 | 0.24 | 0.23 | 0.23 | 0.47 |
| | | | | | | (0.04) | (0.13) | (0.05) | (0.04) | (0.04) |
| Swi | | | | | | | 0.25 | 0.22 | 0.20 | 0.41 |
| | | | | | | | (0.12) | (0.07) | (0.07) | (0.06) |
| Spa | | | | | | | | 0.44 | 0.34 | 0.56 |
| | | | | | | | | (0.16) | (0.21) | (0.16) |
| U.K. | | | | | | | | | 0.56 | 0.70 |
| | | | | | | | | | (0.06) | (0.07) |
| U.S | | | | | | | | | | 0.53 |

1.4.C.- Employment correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.38 | 0.35 | 0.41 | 0.10 | 0.09 | 0.35 | 0.31 | 0.47 | 0.35 | 0.54 |
| | (0.06) | (0.07) | (0.06) | (0.06) | (0.07) | (0.15) | (0.07) | (0.06) | (0.07) | (0.05) |
| Can | | 0.18 | 0.45 | 0.47 | 0.71 | 0.55 | 0.56 | 0.41 | 0.77 | 0.54 |
| | | (0.03) | (0.04) | (0.00) | (0.04) | (0.10) | (0.04) | (0.03) | (0.04) | (0.02) |
| Fra | | | 0.32 | 0.19 | 0.32 | 0.54 | 0.51 | 0.42 | 0.25 | 0.56 |
| | | | (0.08) | (0.06) | (0.06) | (0.14) | (0.08) | (0.05) | (0.05) | (0.06) |
| Ger | | | | 0.45 | 0.42 | 0.59 | 0.58 | 0.10 | 0.38 | 0.72 |
| | | | | (0.05) | (0.06) | (0.05) | (0.09) | (0.06) | (0.06) | (0.07) |
| Ita | | | | | 0.41 | 0.21 | 0.17 | 0.16 | 0.29 | 0.59 |
| | | | | | (0.05) | (0.05) | (0.12) | (0.04) | (0.04) | (0.03) |
| Jap | | | | | | 0.51 | 0.50 | 0.24 | 0.61 | 0.43 |
| | | | | | | (0.01) | (0.08) | (0.03) | (0.02) | (0.03) |
| Swi | | | | | | | 0.35 | 0.28 | 0.44 | 0.53 |
| | | | | | | | (0.04) | (0.02) | (0.01) | (0.04) |
| Spa | | | | | | | | 0.45 | 0.18 | 0.34 |
| | | | | | | | | (0.12) | (0.04) | (0.07) |
| U.K. | | | | | | | | | 0.58 | 0.54 |
| | | | | | | | | | (0.10) | (0.03) |
| U.S. | | | | | | | | | | 0.45 |
| | | | | | | | | | | (0.03) |

1.4.D.- Investment correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.69 | 0.36 | 0.03 | 0.25 | 0.23 | 0.30 | 0.24 | 0.29 | 0.22 | 0.27 |
| | (0.07) | (0.13) | (0.17) | (0.15) | (0.15) | (0.15) | (0.14) | (0.14) | (0.16) | (0.14) |
| Can | | 0.49 | 0.07 | 0.48 | 0.35 | 0.43 | 0.39 | 0.36 | 0.21 | 0.38 |
| | | (0.16) | (0.22) | (0.14) | (0.19) | (0.19) | (0.16) | (0.16) | (0.21) | (0.18) |
| Fra | | | 0.42 | 0.68 | 0.72 | 0.71 | 0.67 | 0.49 | 0.08 | 0.77 |
| | | | (0.20) | (0.10) | (0.09) | (0.15) | (0.18) | (0.17) | (0.21) | (0.13) |
| Ger | | | | 0.23 | 0.55 | 0.55 | -0.01 | 0.13 | 0.43 | 0.77 |
| | | | | (0.17) | (0.16) | (0.18) | (0.21) | (0.20) | (0.18) | (0.14) |
| Ita | | | | | 0.59 | 0.50 | 0.45 | 0.34 | -0.01 | 0.49 |
| | | | | | (0.11) | (0.14) | (0.17) | (0.17) | (0.18) | (0.14) |
| Jap | | | | | | 0.71 | 0.53 | 0.51 | 0.32 | 0.75 |
| | | | | | | (0.10) | (0.18) | (0.18) | (0.21) | (0.10) |
| Swi | | | | | | | 0.43 | 0.35 | 0.37 | 0.73 |
| | | | | | | | (0.10) | (0.19) | (0.20) | (0.14) |
| Spa | | | | | | | | 0.34 | 0.37 | 0.72 |
| | | | | | | | | (0.11) | (0.18) | (0.16) |
| UK | | | | | | | | | 0.43 | 0.60 |
| | | | | | | | | | (0.18) | (0.16) |
| US | | | | | | | | | | 0.45 |
| | | | | | | | | | | (0.19) |

1.4.E.- Productivity correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.23 | 0.25 | 0.31 | 0.18 | 0.24 | 0.10 | 0.09 | 0.07 | 0.31 | 0.26 |
| | (0.08) | (0.08) | (0.06) | (0.05) | (0.06) | (0.04) | (0.03) | (0.19) | (0.10) | (0.07) |
| Can | | 0.16 | 0.37 | 0.42 | 0.48 | 0.47 | 0.18 | 0.31 | 0.78 | 0.36 |
| | | (0.04) | (0.14) | (0.05) | (0.05) | (0.09) | (0.05) | (0.04) | (0.02) | (0.05) |
| Fra | | | 0.48 | 0.62 | 0.46 | 0.49 | 0.24 | 0.36 | 0.28 | 0.67 |
| | | | (0.10) | (0.08) | (0.06) | (0.09) | (0.12) | (0.23) | (0.13) | (0.09) |
| Ger | | | | 0.49 | 0.36 | 0.31 | 0.21 | 0.25 | 0.57 | 0.65 |
| | | | | (0.06) | (0.13) | (0.05) | (0.12) | (0.25) | (0.14) | (0.12) |
| Ita | | | | | 0.34 | 0.62 | 0.43 | 0.32 | 0.44 | 0.57 |
| | | | | | (0.04) | (0.08) | (0.10) | (0.10) | (0.03) | (0.06) |
| Jap | | | | | | 0.43 | 0.11 | 0.14 | 0.49 | 0.48 |
| | | | | | | (0.08) | (0.07) | (0.21) | (0.12) | (0.01) |
| Swi | | | | | | | 0.21 | 0.15 | 0.36 | 0.46 |
| | | | | | | | (0.11) | (0.10) | (0.05) | (0.08) |
| Spa | | | | | | | | 0.23 | 0.34 | 0.62 |
| | | | | | | | | (0.02) | (0.08) | (0.05) |
| UK | | | | | | | | | 0.44 | 0.60 |
| | | | | | | | | | (0.08) | (0.05) |
| US | | | | | | | | | | 0.58 |
| | | | | | | | | | | (0.05) |

1.4.F.- Import correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.49 | 0.47 | 0.40 | 0.61 | 0.35 | 0.50 | -0.23 | 0.44 | 0.54 | 0.51 |
| | (0.12) | (0.18) | (0.12) | (0.06) | (0.12) | (0.10) | (0.06) | (0.20) | (0.13) | (0.15) |
| Can | | 0.06 | 0.16 | 0.33 | 0.06 | 0.44 | 0.14 | 0.25 | 0.68 | 0.24 |
| | | (0.13) | (0.14) | (0.09) | (0.14) | (0.18) | (0.07) | (0.07) | (0.05) | (0.11) |
| Fra | | | 0.73 | 0.82 | 0.78 | 0.69 | -0.10 | 0.49 | 0.44 | 0.90 |
| | | | (0.13) | (0.05) | (0.07) | (0.05) | (0.15) | (0.18) | (0.23) | (0.04) |
| Ger | | | | 0.77 | 0.78 | 0.56 | -0.17 | 0.20 | 0.27 | 0.80 |
| | | | | (0.14) | (0.05) | (0.11) | (0.17) | (0.16) | (0.14) | (0.12) |
| Ita | | | | | 0.78 | 0.69 | -0.08 | 0.52 | 0.55 | 0.91 |
| | | | | | (0.11) | (0.06) | (0.13) | (0.20) | (0.11) | (0.04) |
| Jap | | | | | | 0.53 | -0.27 | 0.37 | 0.24 | 0.83 |
| | | | | | | (0.05) | (0.19) | (0.15) | (0.13) | (0.08) |
| Swi | | | | | | | 0.24 | 0.44 | 0.67 | 0.72 |
| | | | | | | | (0.14) | (0.17) | (0.11) | (0.04) |
| Spa | | | | | | | | 0.17 | 0.17 | -0.01 |
| | | | | | | | | (0.15) | (0.14) | (0.15) |
| UK | | | | | | | | | 0.55 | 0.63 |
| | | | | | | | | | (0.13) | (0.16) |
| US | | | | | | | | | | 0.54 |

1.4.G.-Export correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.56 | 0.08 | 0.05 | 0.08 | 0.03 | 0.19 | 0.08 | 0.19 | 0.29 | 0.17 |
| | (0.05) | (0.08) | (0.07) | (0.11) | (0.09) | (0.12) | (0.15) | (0.07) | (0.11) | (0.07) |
| Can | | 0.33 | 0.12 | 0.34 | -0.08 | 0.49 | -0.03 | 0.37 | 0.48 | 0.39 |
| | | (0.18) | (0.23) | (0.06) | (0.12) | (0.11) | (0.18) | (0.08) | (0.11) | (0.14) |
| Fra | | | 0.71 | 0.50 | 0.63 | 0.65 | 0.18 | 0.48 | 0.43 | 0.89 |
| | | | (0.08) | (0.10) | (0.11) | (0.03) | (0.14) | (0.12) | (0.12) | (0.09) |
| Ger | | | | 0.45 | 0.69 | 0.50 | 0.15 | 0.37 | 0.44 | 0.84 |
| | | | | (0.19) | (0.06) | (0.10) | (0.16) | (0.19) | (0.15) | (0.05) |
| Ita | | | | | 0.36 | 0.48 | 0.09 | 0.54 | 0.24 | 0.60 |
| | | | | | (0.16) | (0.11) | (0.12) | (0.07) | (0.08) | (0.11) |
| Jap | | | | | | 0.39 | 0.16 | 0.23 | 0.34 | 0.61 |
| | | | | | | (0.12) | (0.18) | (0.12) | (0.07) | (0.11) |
| Swi | | | | | | | 0.06 | 0.47 | 0.33 | 0.64 |
| | | | | | | | (0.10) | (0.05) | (0.08) | (0.09) |
| UK | | | | | | | | 0.10 | 0.45 | 0.24 |
| | | | | | | | | (0.15) | (0.15) | (0.13) |
| UK | | | | | | | | | 0.16 | 0.62 |
| | | | | | | | | | (0.22) | (0.11) |
| US | | | | | | | | | | 0.52 |
| | | | | | | | | | | (0.14) |

1.4.H.- Government Spending correlations

| | Can | Fra | Ger | Ita | Jap | Swi | Spa | UK | US | EU |
|---|---|---|---|---|---|---|---|---|---|---|
| Aus | 0.35 | 0.18 | 0.14 | -0.29 | 0.21 | 0.13 | 0.01 | 0.43 | 0.21 | -0.02 |
| | (0.13) | (0.16) | (0.18) | (0.13) | (0.10) | (0.17) | (0.18) | (0.15) | (0.16) | (0.17) |
| Can | | 0.37 | -0.33 | -0.04 | 0.15 | 0.03 | -0.05 | 0.06 | -0.13 | -0.26 |
| | | (0.13) | (0.13) | (0.16) | (0.11) | (0.16) | (0.17) | (0.16) | (0.16) | (0.14) |
| Fra | | | -0.15 | -0.12 | 0.07 | 0.07 | 0.08 | 0.19 | -0.31 | 0.01 |
| | | | (0.17) | (0.17) | (0.11) | (0.18) | (0.19) | (0.17) | (0.13) | (0.18) |
| Ger | | | | 0.25 | 0.17 | 0.25 | -0.05 | 0.32 | 0.27 | 0.72 |
| | | | | (0.17) | (0.10) | (0.17) | (0.18) | (0.15) | (0.15) | (0.09) |
| Ita | | | | | 0.05 | 0.12 | -0.25 | -0.21 | -0.13 | 0.45 |
| | | | | | (0.11) | (0.17) | (0.18) | (0.17) | (0.16) | (0.15) |
| Jap | | | | | | -0.02 | -0.02 | 0.37 | 0.17 | 0.23 |
| | | | | | | (0.11) | (0.11) | (0.06) | (0.11) | (0.10) |
| Swi | | | | | | | -0.12 | 0.20 | -0.02 | 0.21 |
| | | | | | | | (0.18) | (0.16) | (0.16) | (0.17) |
| Spa | | | | | | | | -0.21 | 0.12 | -0.01 |
| | | | | | | | | (0.17) | (0.17) | (0.10) |
| UK | | | | | | | | | 0.19 | 0.42 |
| | | | | | | | | | (0.16) | (0.16) |
| US | | | | | | | | | | 0.17 |
| | | | | | | | | | | (0.16) |

Notes: The data is quarterly and from OECD's Quarterly National Accounts, except for employment which is from OECD Main Economic Indicators, and for Spain which is from INE Contabilidad Nacional Trimestral. The sample period is 1970:1 to 1993:4. Data is Hodrick-Prescott filtered and in logs. Standard errors computed using a Newey and West procedure are in parenthesis.

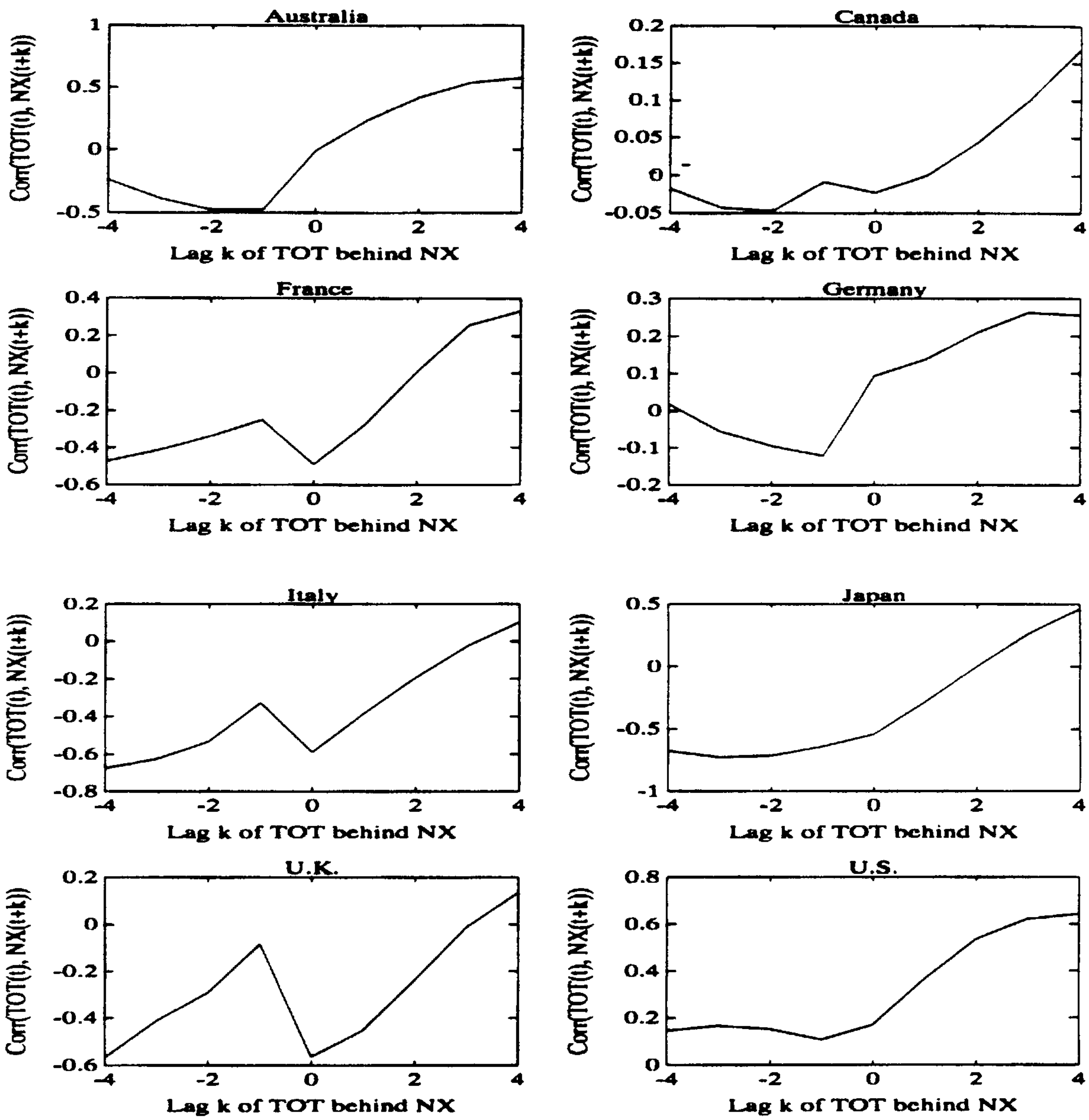


Figure 1.1: S-curve for selected OECD countries

# Chapter 2

# Imperfect Competition*

## 2.1 Introduction

We have seen in Chapter 1 that the neoclassical growth model augmented by technology shocks is able to replicate the main stylized facts of OECD economies. However, there are some aspects of the data that the model fails to replicate, the most prominent being the behaviour of labor markets and foreign trade variables and the pattern of international comovements. In order to solve some of this problems, in this Chapter we examine the properties of an international business cycle model with imperfect competition and indivisible labor. Imperfect competition affects the behaviour of labor markets and is a common feature of models of international trade (see, e.g. Harris (1984) or Helpman and Krugman (1985) among many others) and therefore there are several reasons why this may be an interesting exercise.

First of all, protection in a small open economy may restrict market size and limits foreign competition, promoting many firms which operate at sizes too small in terms of economic efficiency. This is supported by the fact that microeconomic studies have provided evidence of substantial markups of price over marginal cost in many industries and countries (see, e.g., Rotemberg and Woodford (1991) and references therein). However, it is a common feature of macroeconomic models and, in particular, of international business cycle models, to assume perfect competition and constant returns to scale.

Furthermore, as it was first stated by Hall(1988), one of the implicit assumptions of using Solow Residuals as a measure of productivity was the assumption of perfect competition. Hall demostrated that under perfect competition and constant returns to scale Solow Residuals have to be uncorrelated with exogenous variables. He tested this proposition for the U.S. and found the Solow Residual correlated with military spending, interpreting it as evidence in favour of imperfect competition. Ravn (1994) has found similar non-exogeneity results for Denmark, France and the U.K., with the terms of trade being the most important variable explaining Solow Residuals. These findings clearly imply that in order to model an international economy driven by technology shocks we should take into account the existence of imperfect competition.

*This Chapter is a version of Ubide (1995).

In addition, it may be important to check whether the effects of the most popular source of shocks in these models, technological shocks, are robust to the presence of market power. Some authors have examined this issue in closed economies (see, for example, Hornstein (1993) or Rotemberg and Woodford (1992)) by including imperfect competition in dynamic general equilibrium models, and all of them have found imperfect competition to have a significant effect on the variablitity of output and on the behaviour of labor markets. However, nobody has explored the implications of imperfect competition in an open economy framework. This may be important, for example, for issues like the international transmission of shocks, the "twin deficits" (see Baxter (1992)) or the analysis of coordinated government policies (as may be the case for the European Union).

Secondly, as we have already mentioned, the large majority of papers in the International Business Cycles literature focus on productivity and/or government spending shocks as the driving forces of the economy. In this Chapter we put forward an additional source of shocks and transmission of business cycles: exogenous markup fluctuations. In our model, a markup shock is created by a change in the degree of substitutability of goods, that could come, for example, from market saturation and consumer pressure or changes in consumers tastes. Variable markups become a variable that shifts the labor demand curve. For example, consumer pressure could induce a reduction in markups that would increase output, hours and wages. Thus, we have three types of sources of shocks in our model: supply (technology), demand (government policy) and taste/market structure (markup).

Finally, after the seminal paper of Hansen (1985), most of the closed economy models of the Business Cycles consider an indivisible labor structure. This is justified by the fact that in the U.S. about 2/3 of the volatility of total hours worked appears to be due to movements into and out of the labor force, while the remainder is due to adjustment in hours worked by employees, and this percentage is even larger in Europe. Moreover, Zimmermann (1994a) finds that the way labor input is measured is important to determine the size of the volatility of simulated output. Therefore, it seems that the indivisible labor structure can be an appropriate characterization of labor markets in an international business cycle model.

To the best of our knowledge, no one has yet considered the effects of imperfect competition and increasing returns to scale in an open economy framework. In related research in closed economy models, Baxter and King(1990) have analyzed the effect of demand shocks in a competitive enviroment where increasing returns to scale are external to the firm. Rotemberg and Woodford (1992) analyze a variety of models, including one with monopolistic competition, and their implications for output volatility. Hornstein (1993) uses a model with monopolistic competition and increasing returns to scale at the firm's level to analyze the effects of technological shocks on the volatility of U.S. output. Hairault and Portier (1993) analyze the effects of technological and monetary shocks in a model with monopolistic competition and price adjustment. Gali (1994) presents a model where endogenous variations in markups arise from composition effects.

This Chapter presents some international evidence on markups and asks three basic questions: First, are the predictions of standard international business cycle models driven by technological and/or government spending shocks robust to the introduction of imperfect competition? Second, can a model driven solely by exogenous variations in markups account for the business cycle features of international data? Third, can a model driven by combinations of these three sources of fluctuations improve the performance of existing models?

After reviewing in Section 2.2 some of the international stylized facts of labor markets and markups, we present in Section 2.3 a model economy that is an extension of the two country general equilibrium model of BKK (1993) presented in Chapter 1. It is a two-country, two-good general equilibrium model with government in which there are increasing returns to scale at the firm's level and monopolistic competition in national good markets. Aggregate technologies, government spending and markups can be subject to stochastic distubances.

This set of disturbances makes our model considerably richer than standard models, and allows for several ways of transmission of business cycles across countries. First, international cycles may occur because of correlated technological innovations. Second, uncorelated government spending shocks will generate trade in consumption and capital goods, and the possibility of coordinated government policies among groups of countries could drive the economies in certain directions. Third, uncorrelated shocks to markups create international cycles because of their effects in labor markets.

Section 2.4 presents the calibration of the model. In Section 2.5 we discuss the results obtained by simulating different versions of the model with different forcing processes. We analyze several models driven separately by technology and government shocks. In both cases we will compare the cases of perfect competition, imperfect competition with constant markups and imperfect competition with variable markups. In order to better understand the contribution of imperfect competition to the dynamics of the models, we will also study a model driven solely by markup shocks which will also allow us to check whether markup fluctuations can drive the international business cycle. We show that the main results of the standard model are robust to the introduction of imperfect competition, and that this new feature can improve the performance of the models in several respects. Section 2.6 concludes.

## 2.2 Some stylized facts

In this section we compile a set of summary statistics we will use to informally compare the outcomes of our simulations (see Kim and Pagan (1993) or Canova (1994b) for a more formal approach). We refer to Chapter 1 for the general description of the stylized facts of International Business Cycles. There are two additional issues that are important to analyze in some detail in this Chapter. The first one is the behaviour of international labor markets (see Tables (2.1) and (2.2)). Research on the U.S. labor market has stressed the fact that real wages are hardly countercyclical and even procyclical (e.g. Kydland and Prescott (1988)). Some authors (for example, Danthine and Donaldson (1993)) have documented that the labor market behaviour is quite different across countries. However, the procyclicality of hours and productivity and the almost zero correlation of hours and productivity and hours and real wages [2] seems to be a regularity of business cycles across countries. Real wages are in general positively correlated across countries and are either uncorrelated with output or procyclical (in the U.K and in the U.S.)

Given that we are interested in examining the effects of imperfect competition in the model, the second important issue concerns the size and properties of mark-ups across countries. The evidence in the literature is contradictory and refers mainly to the U.S.. Using value added data, Hall(1988) reports values of markups above 2 for the U.S. whereas Domowitz, Hubbard and Petersen (1988) use a highly dissagregated panel data set and find values around 1.6. Recently, Norrbin (1994), introducing intermediate inputs in his data set, has found markups to be considerably smaller, around 1.1. The only non U.S. evidence we are aware of is Portier (1994), who finds a markup of 1,37 for France. Therefore, it seems worthwile to estimate mark-ups consistently for an international data set.

Following Hall (1988) and Rotemberg and Woodford (1991), we use the macro value-added production function

$$y_t = AF(K_t, H_t) - I_t x_t \Phi \tag{2.1}$$

where $K_t$ and $H_t$ are the amount of capital and labor inputs respectively, $I_t$ is the number of firms, $\Phi$ is and overhead or fixed cost, $x_t$ is an exogenous labour augmenting Hicks neutral deterministic technological progress and $A$ is a stationary technology shock.

After log-linearizing around the steady state,

$$\dot{y}_t = \frac{A}{y}\dot{a}_t + \frac{AKF_1}{y}\dot{k}_t + \frac{AxF_2 - Ix\Phi}{y}\dot{x}_t + \frac{AxHF_2}{y}\dot{h}_t + \frac{xI\Phi}{y}\dot{I}_t \tag{2.2}$$

We are assuming that the economy has perfectly competitive factor markets but imperfectly competitive goods markets. This has the implication that firms have some market power, represented by the level of markup $\mu$ (the ratio of factor marginal remuneration over factor marginal productivity). The aggregate factor demands at the steady state are given by

$$\begin{aligned} AF_1 &= \mu^{*} r \\ AxF_2 &= \mu^{*} w \end{aligned} \tag{2.3}$$

Expressing the payments to capital and labor in terms of factor shares (i.e. $sk = rk/y$),

$$\begin{aligned} AF_1 \tfrac{K}{Y} &= \mu^{*} sk \\ AxF_2 \tfrac{H}{Y} &= \mu^{*} sh \end{aligned} \tag{2.4}$$

Since F is homogeneous of degree one, we have

[2] This fact has been named the Dunlop-Tarsis observation: low correlation between return to working and hours worked, regardless of whether the return to working is measured as the real wage or average productivity, see Dunlop (1938) and Tarsis (1939)

$$1 = \frac{AF_1}{Y}K + \frac{AxF_2}{Y}H - \frac{Ix\Phi}{Y} \tag{2.5}$$

Assuming that all the technological progress is labor augmenting (so that $\dot{a}_t=0$), using (2.2), (2.3), (2.4) and (2.5), we obtain the expression for true technological progress:

$$\dot{x}_t = \frac{\dot{y}_t - \mu^* sk\, \dot{k}_t - \mu^* sh\, \dot{h}_t - s_\phi\, \dot{I}_t}{1 - \mu^* sk} \tag{2.6}$$

Solving for $\mu$ in eq. (2.3) and log-linearizing

$$\dot{\mu}_t = \dot{x}_t - \dot{w}_t + \frac{\mu^* sk}{\epsilon}\left(\dot{k}_t - \dot{x}_t - \frac{\mu^* sh}{1 - \mu^* sk}\dot{h}_t\right) \tag{2.7}$$

Substituting $\dot{x}_t$ from (2.6) we obtain an expression for the markup series:

$$\dot{\mu}_t = \frac{e - \mu^* sk}{e - e\mu^* sk}\dot{y}_t + \frac{(1-\epsilon)\mu^* sk}{e - e\mu^* sk}\dot{k}_t - \frac{\mu^* sh}{1 - \mu^* sk}\dot{h}_t + \frac{s_\phi(\epsilon - \mu^* sk)}{e(1 - \mu^* sk)}\dot{I}_t - \dot{w}_t \tag{2.8}$$

Because of the lack of data for the rental price of capital and the number of firms at quarterly frequency and over a large sample, we will proxy the variations of markups by

$$\dot{\mu}_t = \frac{\epsilon - \mu^* sk}{\epsilon - e\mu^* sk}\dot{y}_t - \frac{\mu^* sh}{1 - \mu^* sk}\dot{h}_t + \dot{w}_t \tag{2.9}$$

However, as BKK(1992) pointed out, the cyclical variability of capital is small compared with that of output so that the omission of this variable from equation (2.9) is not relevant. We also assume that entry and exit of firms is not instantaneous, and therefore the cyclical properties of markups may be well represented by this proxy. In order to estimate these series we need values for the parameters e and $\mu^*$.

e is the elasticity of substitution between factors in the production function. It is equal to 1 in the case of Cobb-Douglass production function. Therefore, we use the value e=1 as a benchmark and perform some sensitivity analysis with values in the range [0.5 2].

$\mu^*$ is the average markup. Following Hall, we will impose the restriction that the measure of technical progress given by equation (2.6) has to be orthogonal to a pure demand shock. This is implemented impossing Cov $(x_t(\mu^*), \varepsilon_{gt}) = 0$, where $\varepsilon_{gt}$ is the residual of fitting an AR(1) process with $\rho_g = 0.95$ to the detrended government expenditure series. This parameter is estimated by GMM for the set of countries using data from OECD Main Economic Indicators for the period 1979:1-1993:4. We assume that technical progress follows a stationary process around a linear trend, and therefore $\hat{h}, \hat{y}, \hat{w}$ and $\hat{g}$ are computed as log deviations from that trend. $\hat{y}$ is Gross Domestic Product, $\hat{h}$ is total hours worked per quarter, $\hat{w}$ is average weekly earnings and $\hat{g}$ is total government spending.

The results of our exercise appear in Table (2.3). Our estimates of the average markup lie in the range [1.32 1.56]. These results are a bit lower than estimates obtained using panel data (at least for the U.S. economy), and therefore some microeconomic analysis should be carried out in order to confirm these values.

The plots (see Figure (2.1)) seem to suggest that markups are countercyclical. In order to properly check this issue, we present in Table (2.5) the values of the contemporaneous correlation coefficient between output and markups for different values of $\mu^*$ and e. In all cases except for France the values are negative, increasing with $\mu^*$ and decreasing with e. This sensitivity of the results to the parameters suggests that further empirical work is needed to put the cyclical properties of markups on a clear stand.

The correlations of markups at an international level do not display a clear pattern of behaviour. We can see in Table (2.4) that the cross-country correlation coefficients range from -0.54 between France and Canada to 0.80 between Canada and the U.S. Therefore, we do not find evidence of correlated markup shocks as a way of transmission of business cycles across countries.

## 2.3 The model

The theoretical economy we use extends the standard model of BKK(1993) presented in Chapter 1 to include government spending, indivisible labor and imperfect competition. There are two countries, each of which specializes in the production of one tradable good. We assume that there are increasing returns to scale and noncompetitive behaviour in the goods markets and competitive behaviour in the production factors market.

Countries are populated by a large number of utility maximizers infinitely-lived identical agents. The household sells the services of capital and labor at rental prices $r_t$ and $w_t$ respectively, owns all the firms and receives all the profits. The differentiated goods produced by the monopolistic firms will be purchased by the household to be consumed or invested. There are complete financial markets within countries and free mobility of physical and financial capital across countries. However, labor is immobile internationally.

Each household in country $h$ has preferences given by the utility function

$$U_{ht} = E_0 \left[ \sum_{i=0}^{\infty} \beta^i u(c_{ht+i}, G_{ht+i}, l_{ht+i}) \right] \tag{2.10}$$

where $U_{ht}$ is the total discounted lifetime utility, E is the conditional expectations operator and $\beta$ is the subjective discount factor. The instantaneous utility function, $u(.)$, is given by

$$u_h(c_{ht}, l_{ht}) = \log c^*_{ht} + D \log l_{ht} \tag{2.11}$$

where $c_{ht}$ is per capita consumption of the final aggregate good at time t, $l_{ht}$ is leisure, D is a constant and $c^*_{ht} = c_{ht} + \phi_g G_{ht}$ is a measure of consumption. We allow the agents to derive some utility from government spending, in particular that government spending has some effect on the marginal utility of consumption as measured by the parameter $\phi_g$. If $\phi_g = 1$ then private and government consumption are perfect substitutes and government just crowds out private consumption, whereas if $\phi_g = 0$ government consumption has no effects on private utility and government expenditure can be thought just as a drain of resources. If $0 < \phi_g < 1$ consumption and government consumption are imperfect substitutes and therefore it is costly for society to have government producing these goods. As Canova (1993a) points out, a way to see this is to assume that the government has a linear technology of the type $z_t = \phi_g G_t$. If $\phi_g < 1$, production of these goods by the government is inefficient.

The endowment of time is unity in each period, which constrains leisure to be between 0 and 1. This choice is further restricted by the introduction of an indivisible labor structure: the household can either work a fixed amount of time or not to work at all. Following Rogerson (1988) and Hansen (1985), we convexify the consumption set by adding lotteries to the commodity space. In particular, during period t the representative household can either work full time ($h_0$ hours, $0 < h_0 < 1$) with probability $\pi_t$ or not work at all with probability $(1 - \pi_t)$. Ex-post, $\pi_t$ will be the actual number of people working and hence per capita hours will be $h_t = \pi_t h_0 = 1 - l_t$. The utility function of the representative agent is then,

$$u_{ht} = \pi_t \left(\log c^*_{ht} + D \log(1 - h_0)\right) + (1 - \pi_t)\left(\log c^*_{ht} + D \log 1\right) \tag{2.12}$$

which substituting for leisure simplifies to the following expression:

$$u(c_{ht}, l_{ht}) = \log c^*_{ht} + \frac{D \log(1 - h_0)}{h_0} - \frac{D \log(1 - h_0)}{h_0} l_{ht}$$

We can see that, due to the indivisible labor structure, the intertemporal aggregate elasticity of substitution of leisure is infinite and independent of the individual preferences.

There exists a continuum of potentially producible different goods indexed by the positive real line, and only $[0\ I_t]$ are produced at each time t. There are j sectors in the economy. In each sector there is a representative firm j that produces good j using capital (K) and labor (H) according to the following value-added increasing returns to scale production function

$$y_{ht}(j) = \left(A_{ht} K_{ht}(j)^{\alpha} (x_{ht} H_{ht}(j))^{1-\alpha_j}\right)^{\gamma_{kn_j}} - \Phi_h \tag{2.13}$$

Production is subject to a stationary technological shock $A_{ht}$ that affects equally all sectors. $\Phi_h$ represents a fixed or overhead cost component, which permits the existence of increasing returns to scale without generating positive profits on average, a fact that has been documented for the U.S. by Hall(1990) and Summers (1981) among others. The scale parameter $\gamma_{kn_j} > 1$ also implies increasing returns to scale. $x_{ht}$ represents the state of technology at time t, and in particular an exogenous labour augmenting Hicks neutral deterministic technological progress.

Aggregating across sectors, we obtain the macro value-added production function,

$$y_{ht} = \left(A_{ht} K^{\alpha}_{ht} (x_{ht} H_{ht})^{1-\alpha}\right)^{\gamma_{kn}} - I_{ht} \Phi_h \tag{2.14}$$

where $I_{ht}$ is the number of firms. Because we are assuming a representative firm in each sector, $I_{ht}$ can be thought of as the number of different sectors or industries of the economy at any point in time.

Feasibility requires:

$$\begin{aligned} \int H_{ht}(j)d_j &\leq H_{ht} \cdot \\ \int K_{ht}(j)d_j &\leq K_{ht} \end{aligned} \tag{2.15}$$

The markup ratio, $\mu_{ht}$, represents the inverse of the Lagrange multiplier associated with the requirement that the firm produces a given level of output. It also represents the ratio of factor marginal productivity over factor marginal remuneration (which is different from the ratio of price over marginal costs if materials enter the production function, see Rotemberg and Woodford(1992)) and therefore it depends on the degree of substitutability of goods in the market and the degree of market power that firms have. In the case of perfect competition, goods are perfect substitutes and therefore $\mu_{ht} = 1, \forall t$. The existence of imperfect competition implies that goods are imperfect substitutes and thus there exists an efficiency wedge or markup, $\mu_{ht} > 1$, between marginal products and factor prices at the aggregate level. Conditional factor demands in this economy are then given by

$$F_1(K, H) = \mu_t r_t \tag{2.16}$$

$$x_t F_2(K, H) = \mu_t w_t \tag{2.17}$$

where $F_1$ and $F_2$ are the derivatives of the production function (2.13) with respect to capital and labour respectively. We will consider exogenous variations in the degree of market power that could arise, for example, from variations in the degree of substitutability between differentiated goods. This implies considering shocks to markups as a source of disturbances that can be transmitted internationally. An alternative route could have been to consider markups as a transmission mechanism of exogenous shocks, and in which case markups would have been determined endogenously. Rotemberg and Woodford (1992) survey several models of endogenous markup determination. These models make different assumptions on the underlying market structure, and make markups dependent on state variables such as output or profits. In our model we assume that markups vary over time according to the law of motion

$$\ln \mu_{ht} = \rho_\mu \ln \mu_{ht-1} + \epsilon_{\mu t} \tag{2.18}$$

where $\rho_\mu < 1$. Since we are interested in short run fluctuations, the number of firms $I_{ht}$ will be treated as exogenous, although we could argue that long run growth could increase the number of industries in an economy since firms will enter or exit the market depending on the level of profits. Whenever there are positive profits firms will enter the economy, creating new diferentiated products, and vice versa. Therefore, we are considering adjustment in the number of industries, and not in the number of firms in each industry. However, we will assume that firms do not react rapidly to technological shocks (see, i.e. Cardia and Ambler (1993) or Portier(1994) for specifications with instantaneous entry and exit of firms). This can be implemented by specifying (as it is done, for example, in Rotemberg and Woodford (1992)), a law of motion for the number of firms that follows an ECM process of the type

$$\log I_{ht} = k \log(I_h x_{ht} H_{ht}) + (1-k) \log I_{ht-1} \tag{2.19}$$

with $k$ small to ensure a slow adjustment, $0 < k <= 1$ and $I_h > 0$ is the steady state number of firms in country $h$. Since $I_{ht}$ grows with $x_{ht}$, this specification ensures that profits remain zero in the steady state.

Firms accumulate capital goods according to the law of motion

$$K_{h,t+1} = (1-\delta)K_{ht} + i_{ht} \tag{2.20}$$

where $K_{ht}$ is total stock of capital in country $h$, $\delta_h$ is the rate of depreciation of capital stock and $i_{ht}$ is total investment in country $h$.

The stationary technological disturbance follows the autoregressive process

$$\ln A_{ht} = \rho_a \ln A_{ht-1} + \epsilon_{at} \tag{2.21}$$

where $\rho_a < 1$. In addition to consumers and producers, there is a government in each country. The government consumes domestic goods ($G_{ht}$), taxes national output with a distorsionary tax ($\tau_h$) and transfers back the remaining to domestic residents ($T_{ht}$). Government expenditure is assumed to be stochastic following the process

$$\ln G_t = \rho_g \ln G_{t-1} + \epsilon_{gt} \tag{2.22}$$

where $\rho_g < 1$. In order to isolate the effects of government expenditure and differently from the optimal taxation literature that models taxes as a stochastic process, we will set tax rates parametrically (see Baxter (1992) or Kollmann (1993) for an analysis of stochastic tax rates in an open economy model). Since taxes are distortionary, we will have to make some assumptions at this stage in order to solve for the competitive equilibrium. We will assume that individuals take government actions as given, which is consistent with the existence of a large number of individuals (see KPR (1988b) for a complete description of how to compute this suboptimal equilibrium). This means that we can solve for the competitive equilibrium by first solving for the individual problem and then imposing the government flow budget constraint, that is given by

$$G_{ht} = T_{ht} + \tau_h Y_{ht} \tag{2.23}$$

and has to hold on a period by period basis. To allow for balance growth, we will assume that both government spending and transfers grow with $x_{ht}$.

It is important to note that this economy encompasses the perfect competition environment, which can be recovered by setting $\Phi = 0$ and $\mu = \gamma_{kn} = 1$.

Foreing trade can be introduced in the model by assuming that a foreign firm is considered a competitor just like any other. However, given that the data show that domestic consumers tend to consume more products from domestic firms than they do from foreign firms, we open the economy as in Chapter 1 by assuming that $Y_{ht}$ can be either used domestically or exported

$$Y_{1t} = A_{1t} + \frac{\Pi_2}{\Pi_1}\tilde{A}_{2t} \tag{2.24}$$

$$Y_{2t} = B_{1t} + \frac{\Pi_1}{\Pi_2}\tilde{B}_{2t} \tag{2.25}$$

where $\tilde{A}_{2t}$ and $B_{1t}$ are exports and imports of country 1 and $\Pi_h$ is the welfare weight associated with country $h$, $\Pi_1 + \Pi_2 = 1$. We let $A_{2t} = \frac{\Pi_2}{\Pi_1}\tilde{A}_{2t}$ and $B_{2t} = \frac{\Pi_1}{\Pi_2}\tilde{B}_{2t}$. Imports and domestic market goods are then used in the production of a final domestic market good in each country, $V_{ht}$, according to a CES technology of the form (see Armington (1969)):

$$V_{1t} = (\varpi_1 A_{1t}^{1-\rho} + \varpi_2 B_{1t}^{1-\rho})^{\frac{1}{1-\rho}} \tag{2.26}$$

$$V_{2t} = (\varpi_1 B_{2t}^{1-\rho} + \varpi_2 A_{2t}^{1-\rho})^{\frac{1}{1-\rho}} \tag{2.27}$$

where $\varpi_1$ and $\varpi_2$ are parameters regulating the domestic and foreign content of GNP and $1/\rho$ is the elasticity of substitution between domestic and foreign goods. Therefore, this specification allows for higher weights on domestic goods than on foreign goods. Moreover, as long as $1/\rho$ is finite this aggregator embodies the idea that consumers regard goods produced by different firms as imperfect substitutes and prefer variety. If $1/\rho$ is infinite, however, the goods produced by different firms are perfect substitutes and therefore homogeneous. The relative price of imports to exports (terms of trade) is then given by:

$$P_{1t} = \frac{\partial V_1/\partial B_{1t}}{\partial V_1/\partial A_{1t}} = \frac{\varpi_2 B_{1t}^{-\rho}}{\varpi_1 A_{1t}^{-\rho}} \tag{2.28}$$

where $\varpi_1 = (1 - MS)^\rho$, $\varpi_2 = MS^\rho$ and where $MS$ is the import share in output.

The aggregate resource constraint for the traded goods in the world economy is

$$\Pi_1 V_{1t} + \Pi_2 V_{2t} = \Pi_1(c_{1t} + i_{1t} + G_{1t}) + \Pi_2(c_{2t} + i_{2t} + G_{1t}) \tag{2.29}$$

Note that when the two countries are equally wealthy in per capita terms, $\Pi_i$ $i = 1,2$ measure the number of agents in each country. Therefore, we can meaningfully discuss country size in the model by varying these weights between 0 and 1.

Now we compute a symmetric, stationary, rational expectations, monopolistic competitive equilibrium. The equilibrium is symmetric because all producers produce the same quantity and charge the same price. Once equilibrium prices and profits are determined as functions of the states, the representative household's dynamic optimization problem will be solved, taking as given the laws of motion for the aggregate state variables.

We first convert the system into a non-growing stationary representation. This ia done by dividing all the variables by the Hicks-neutral technological progress variable $x_t$. Since the funcional forms allow for balance growth, all output components will grow at a common rate while hours worked and leisure will not grow at all. Then we solve a pseudo social planner problem in which first individuals take government behaviour as given and then the planner includes the government budget constraint in order to make individual actions consistent with aggregate constraints. As it is well known, this problem does not have a closed form solution and we have to approximate and solve it numerically. Among the many ways of doing this (see Marcet (1993) for a survey) we follow KPR(1988c) by linearizing the first order conditions around the steady state.

We construct 100 samples of 96 periods (the number of quarters of our data) each time drawing shocks from (2.18), (2.21) and (2.22) for each model specification. Each sample is Hodrick-Prescott filtered and standard deviations and cross correlations are computed. Finally, statistics are averaged over the 100 samples to reduce the importance of sampling variability in the comparisons.

## 2.4 Calibration of the economy

In calibrating the parameters of the model we follow the existing practice of choosing share parameters to replicate long run averages of the data and utility parameters to match estimates obtained in previous empirical studies. The values that we have selected for $\beta = 0.98$, $\delta_k = 0.025\%$, $\Pi_1 = \Pi_2 = 0.5$ are standard and do not require discussion. $h_0$, the fixed amount of hours that the household works per day is computed so that it is consistent with the steady state amount of hours worked, $h = 0.33$. Dividing the first order condition for consumption by the first order condition for labor we have

$$\frac{\Omega\frac{\gamma}{\mu}\frac{Y+\phi I}{Y}(1-\alpha)}{(sc+\phi sg)h} = \frac{D\log(1-h_0)}{h_0} \tag{2.30}$$

Setting the leisure constant D equal to 2 as in Hansen (1985) gives a value of $h_0 = 0.42$.

Evidence on the parameter $\phi_g$, the effect of government spending on private utility is scant. Ashauer(1985) found a value of 0.2, and this is the value used by Ravn (1993) or Canova (1993a). We will use this value as a benchmark and experiment with values in the range [0 1] in order to see how variations in this parameter affect the results.

Ravn(1993) reports the mean shares of output components for several OECD countries. The mean shares of government expenditures are diferent across countries, ranging from 10 % in Japan to 28 % in Sweden. However, most countries of his panel are close to 20 % and we will take this value for our simulations. The investment share is then determined endogenously in the model, and the consumption share will be the residual of these two. The values that we obtain for the benchmark parameterization are I/Y =0.26 and C/Y=0.53, which describe reasonably well OECD economies. The constant tax rate will be set to 30 %, implying an amount of steady state transfers of 10 % of GNP.

For the share of imports $MS$ and the elasticity of substitution of the Armington aggregator

$\rho^{-1}$ we use standard values suggested in the literature. Empirically, $MS$ varies substantially across countries, normally being higher for smaller countries. Ravn (1993) reports values ranging from 38.6% for Switzerland to 7.7% for the U.S. BKK (1992) use two values (15% and 30%) as a 'normal' and 'large' import share. Here we choose the cross sectional average of the OECD countries 22.5%. (as in Ravn (1993)) for the benchmark case.

Values for $\rho^{-1}$ of 1-1.5 have been generally used in general equilibrium models of trade but they are believed to be lower bounds for the actual value since estimates of this elasticity parameter are downward biased because of large measurement errors (see Whalley (1985)). Zimmermann (1994a) obtains an expression for this elasticity in his model that depends on tariffs, transportation costs, import shares and terms of trade. His corresponding estimates for OECD countries are in the range [0.6-13.5], averaging 5.4. In order to compare with previous work, we use 1.5 as in BKK (1992) for the benchmark case.

The next set of parameters is related to the existence of market power. Evidence on $\gamma_{kn}$ is scarce. Ramey (1989) and Morrison (1990) report estimates that indicate the presence of declining marginal cost in several industries in the U.S. Because of this scarcity, we will set it equal to 1.2 and will perform some sensitivity analysis. Average markup, $\mu_{kn}$ , will be set equal to 1.4, the mean value across countries of our estimates, but some sensitivity analysis will be carried out to check how results vary with $\mu_k n$. The overhead cost $\Phi$ is set such that profits are zero in the steady state .

$\alpha$, the share of capital in the production function, is set to 0.36 which is, approximately, the mean value of the share of capital in production for developed countries (see Zimmermann (1994a)). Given $\delta_k, \gamma_{kn}, \alpha$ and $\mu_{kn}$, the K/Y ratio is computed endogenously from the first order condition for the capital stock.

The exogenous elements of the economy are assumed to follow a first order Markov process

$$A_{t+1} = C(L)A_t + \epsilon_{t+1} \tag{2.31}$$

where $A_{t+1} = [A_{1t}, A_{2t}, G_{1t}, G_{2t}, \mu_{1t}, \mu_{2t}]'$ and $\epsilon_t \sim N(0, V)$. We have therefore to choose parameters for C(L) and V, the variance-covariance matrix. It is widely recognized that direct estimation of these parameters is problematic. In our case it is even more difficult, because we would have to estimate a six variable VAR in which four of the variables are unobservable (technology and markups). Therefore, we will follow a different approach (as it is done for example in Baxter and Crucini (1993)) and select the parameters in order to model different scenarios we may envisage. This will also allow us to compare our results with those existing in the literature and isolate the effects of imperfect competition. The benchmark model will be a standard symmetric model. The persistence of the technological process is set to 0.835 as in Ravn(1993), since it is an average of the estimated parameters for the major OECD countries. The cross-country correlation is set to 0.25 and the spillover parameter to 0.088 as in BKK(1993).

The persistence of government spending is set to 0.95 and the standard deviation to 0.005 as in Ravn(1993). However, we will also use the values 0.90 and 0.99 in order to study the effects of temporary and permanent shocks, as it is done in Baxter (1992). In the case when coordinated policies are considered, the cross-country correlation coefficient is set to 0.20 in the case of low policy coordiantion and to 0.60 in the case of high coordination. Christiano and Eichenbaum (1992) consider the possibility of government spending shocks being correlated with technological shocks, as it could be the case of a technological shock induced by an increase in publicly financed research. For these cases, the correlation parameter between technological and government shocks will be again 0.20 and 0.60.

Markups follow also an autoregressive process. We believe that this process is quite likely to be persistent and therefore we choose a persistence parameter of 0.95 and standard deviation of 0.007 as in Rotemberg and Woodford (1992). Cross-country correlations are set to zero because we did not find any clear patern in the data.

With this parameterization, we will analyze several models driven separately by technology and government shocks. In both cases we will compare the cases of perfect competition, imperfect competition with constant markups and imperfect competition with variable markups. In order to better understand the contribution of imperfect competition to the dynamics of the models, we will also study a model driven solely by markup shocks which will also allow us to check whether markup fluctuations can drive the international business cycle. Therefore, the models we will consider are:

- A standard perfectly competitive model with technological shocks (Model T1).
- An imperfectly competitive model with technological shocks (Model T2).
- An imperfectly competitive model driven by markup shocks (Model M1).
- An imperfectly competitive model driven by technology shocks with variable markups (Model TM1).
- A perfectly competitive model driven by government spending shocks (Model G1).
- An imperfectly competitive model driven by government spending shocks (Model G2).
- An imperfectly competitive model driven by government spending shocks with variable markups (Model GM1).
- An imperfectly competitive model driven by combinations of both technology and government shocks (Model TG1)
- An imperfectly competitive model driven by combinations of both technology and government shocks with variable markups (Model TGM1)

For each model specification in which there are technology shocks we will consider three subcases: in the first one (named S1) shocks are uncorrelated across countries and there are no spillovers either domestically or internationally. This setup mimics a situation where countries face idiosyncratic disturbances but move together over the business cycle because of trade interdependencies. The second setup (named S2) has correlated shocks and no spillovers. Here we try to mimic a typical situation in OECD countries where nations face somewhat common disturbances but there is very little evidence of lagged transmission of these shocks. In the third setup (named S3) we consider an economy with correlated shocks and spillovers, a scenario which may realistically resemble the economic environment of highly integrated economies like the European Union.

## 2.5 Simulation Results

### 2.5.1 Models with Technology Shocks

#### Standard Model with Technology Shocks

In Table (2.6) we present statistics for a symmetric model with constant returns to scale driven by disturbances to the market technology (model T1), which serves as a benchmark to compare the improvements obtained with alternative specifications. Figure (2.2) shows the dynamics of the model following the shock. The model works well along some dimensions but there are at least five aspects of the data which are mismatched. First, output, consumption, hours, imports and exports do not fluctuate enough relative to the data. Second, hours, investment and imports are too highly correlated with output while the correlation between exports and output is too small. Third, real wages are strongly procyclical and hours worked and the return to working are too strongly correlated relative to the data. Fourth, consumption is more correlated than output across countries while in the data the opposite is true. Fifth, investment, hours, imports and exports are either negatively correlated or show no correlation across countries. All of these facts emerge because there is only one source of shocks, investment drives the cycle and capital markets are complete

We will focus on these aspects of the models when examining the improvements obtained with alternative specifications.

#### Standard Model with Technology Shocks and Imperfect Competition

The addition of imperfect competition (model T2) alters the dynamics of the model. The presence of markups and increasing returns to scale tends to amplify the effects of the technological shock. Market power allows firms to set the marginal product of labor higher than the wage and therefore a technological shock, which represents an increase in the effective units of labor that firms hire, produces, in the presence of imperfect competition, an increase in effective labor input that leads to a higher level of investment and raises output more than under perfect competition. The dynamics of the model for the specification S1 appear in Figure (2.2). We can see that, as a result of the technology shock, output, investment and productivity respond more compared to the perfect competition case, whereas the behaviour of the rest of domestic variables remain unaltered. This larger increase in domestic investment creates a big boom in foreign exports producing, for the same technology differential, a greater increase in foreign output and hours and a smaller decrease in investment.

As a result, output and productivity fluctuate more whereas employment and investment and therefore foreign trade variables fluctuate less. Confirming the results already obtained in closed economy models, the introduction of imperfect competition raises the volatility of productivity above that of hours, solving one of the aspects of the labor market puzzle. Domestic comovements are barely affected as are international ones, and only cross-country consumption correlations increase slightly because although foreign consumption decreases more after the shock it returns faster to the steady state and therefore the path of consumption in both countries is more similar.

These results are robust to reasonable variations in the imperfect competition parameters, the scale parameter $\gamma_{kn}$ and the average markup, $\mu_{kn}$. Figure (2.14) shows how second moments vary with different values of these parameters. First of all, we can see that variations in $\gamma_{kn}$ have almost no effect on the results, just increasing slightly output and investment volatility.

Variations in market power have a more sizable effect on the variables of the model. As average markups increase, output and productivity fluctuate more and investment, hours and the foreign trade variables fluctuate less. This raises the procyclicality of productivity and decreases that of investment, hours and wages. Therefore, increases in market power just amplify the effects of imperfect competition mentioned above although, for values of markup above 1.8, we obtain the counterfactual result that the volatility of output becomes higher than that of investment.

### Model driven by Markup Shocks

M1 is a model in which the only source of disturbances is shocks to markups. We can see that it works reasonably well along several lines. Compared to the standard model, it fails to reproduce the volatility of hours and average productivity and the procyclicality of consumption, average productivity and wages, but produces procyclical exports and improves international comovements, since it generates positive cross-country correlations of output, average productivity, hours and wages and lowers the negative correlation of investment, imports and exports.

The dynamics of the model are displayed in Figure (2.3). An increase in markups produced by, for example, a change in the degree of substitutability of goods after a change in the consumer tastes, decreases the rate of return on production factors, and therefore hours and investment decrease creating a recession, an effect in some sense similar to an adverse technological shock. This seems to be in agreement with the empirical evidence about the countercyclicality of markups. Consumption increases slightly at the moment of the shock due to the transfer of resources from investment, but goes down immediately due to the negative wealth effect. The international reallocation of capital goods and the improvement in the terms of trade produces an improvement in net exports. However, as soon as the shocks are transmitted, investment declines in the foreign country before returning to the steady state, and therefore this model generates cross-country investment correlations that are almost positive, and the same happens with imports and exports. A final important aspect is the behaviour of labor markets. A markup shock implies an increase in real wages, that goes along with a decrease in output and productivity, therefore creating countercyclical movements in wages.

**Model with Technology Shocks and Imperfect Competition with variable Markups**

The combination of technology and markup disturbances (Model TM1) improves the behaviour of the standard model along several lines. The volatility of hours and productivity increases. Hours, productivity and wages are less procyclical, whereas exports become positively correlated with output. Regarding cross-correlations, output, consümption, hours and wages correlations increase, whereas investment, exports and imports are less negatively correlated across countries. The behaviour of the labor market variables also improves, with hours now bring substantialy less correlated with both wages and productivity.

The main diference in the dynamics of the model relative to the standard model is that now after the shock investment increases quite less, due to the effect of markups, and therefore output increases only moderately. Hours decrease and wages slightly increase. After the impact, both hours, output and investment decrease, becoming even negative before rising again while returning to the steady state. Therefore, the introduction of variable markups reduces the procyclicality of almost all the variables.

The effects of the shocks in the foreign country are similarly milder. At the impact investment decreases less than in the standard model. This fact implies that net exports deteriorate less in the home country, although the level of countercyclicality is almost the same. After the impact, investment, hours and output in the foreign country increase in their way back to the steady state. This implies positive cross-country correlations (or at least less negative) in output, investment, productivity and hours.

The sensitivity of these results to variations in the imperfect competition parameters ($\gamma_{kn}$, $\mu_{kn}$, $\rho_{\mu}$ and $\sigma^2_{mu}$) can be seen in Figs. (2.15) and (2.16). As in model T2, variations in $\gamma_{kn}$ have no qualitative effect on any of the results. Likewise, as $\mu_{kn}$ increases the volatility of output increases whereas the volatility of investment, labor and the foreign trade variables decreases. It is interesting to see that there is a sizable effect on the correlation between productivity and output or labor, with the coefficients increasing as the parameter increases. The rest of domestic and international comovements remain essentially unchanged.

Similarly, the choice of the parameters of the markup process does not affect significantly the results. The value of the persistence parameter does not affect volatilitites, and changes only slightly some of the correlations of labor market variables. The volatility of markups has a more sizable effect, although it does not qualitatively affect any of the results. Logically, increases in the volatility of markups increases output and investment volatility and therefore decreases the procyclicality of wages and productivity.

Hence, the introduction of imperfect competition with variable markups improve the behaviour of the standard model along several lines, lowering the procyclicality of domestic variables, improving the matching of the second moments of labor market variables and increasing the cross-country correlations of the main variables. However, the model is not able neither to raise the volatility of foreign trade variables nor to obtain output correlations larger than the correspondent consumption correlations (the risk sharing puzzle). All these results are robust to variations of the imperfect competition parameters within a sensible range.

### 2.5.2 Models with Government Spending shocks

#### Model with Government Shocks and Perfect Competition

Table (2.7) shows the second moments of a model driven by an aggregate demand shock in the form of an increase in government spending. This model is able to account for some of the volatilities of domestic business cycles. The variability of output is quite low, but the relative variabilities with respect to output are reasonably well reproduced by the model, with the exception of hours, that fluctuate too much. Foreign trade variables are more volatile than in a model with technological shocks and are close to those found in the data.

Domestic comovements do not match the data well, since the model fails to capture the procyclicality of consumption, productivity, wages and exports and produces low saving-investment correlations. However, the model does a good job as far as international comovements are concerned, since it creates positive correlations across countries in output, consumption, investment, hours and wages. Furthermore, with $\phi_g > 0$ the model is also able to solve the risk sharing puzzle, producing consumption correlations that are lower than output correlations. However, imports and exports remain negatively correlated. It is important to note that the high saving-investment correlations are not a property of a perfectly competitive model driven by government shocks.

The dynamics of this economy are as follows (Figure (2.4)). An increase in government purchases increases the world interest rate and produces a negative wealth effect in both countries. The increase in government spending financed by taxes decreases household's income, leading to a decrease in both consumption and leisure. This raises labor supply and lowers wages, and therefore increases the return on capital and investment. Neither national production nor national savings are enough to cover this investment boom, and therefore imports increase substantially. Therefore, on impact there is a small decrease in consumption (with $\phi_g$ =0) and an increase in hours, investment and output in both countries due to the perfect capital markets assumption. In a one good world, the responses in both countries would be identical. In this economy with two goods and imperfect substitution between them the responses are similar but not identical, and therefore we obtain positive comovements across countries. The only cross-correlations that remain negative are imports and exports, because in the foreign country imports increase to meet the investment boom whereas exports decrease. The foreign country does not need an increase in imports because the investment boom is small, and therefore we have asymmetric movements in these variables.

Modifications of the parameter $\phi_g$, the effect of government spending on private utility have a significant effect on the performance of the model, in particular when $\phi_g = 1$. An increase in the degree of substitutability of government goods decreases (increases) output (consumption) volatility , and in the case of $\phi_g = 1$ output (consumption) volatility is equal to zero (one hundred). This is so because if private and public goods are perfect substitutes and increase in government spending just crowds out private consumption, leaving output unaltered. A second effect of having $\phi_g$=1 is that it lowers the countercyclicality of consumption, productivity and wages, these last two becoming procyclical. This happens because output is unaltered in this case and therefore consumption now is uncorrelated with output.

It is interesting to note that the correlation between saving and investment is quite low, and decreases with $\phi_g$. An increase in government purchases in this economy increases output and decreases consumption, leading to a small increase in savings (S=Y-C-G), but pushes up investment, creating a gap between these two variables that will be filled by imports. As $\phi_g$ increases this gap widens, lowering the correlation.

An interesting property of the model with $\phi_g$ different from zero is that we obtain cross-country consumption correlations that are lower than cross-country output correlations, although in the case of $\phi_g = 1$ both correlations are almost zero, and the same happens with productivity, hours and wages. Finally, with $\phi_g = 1$ the model is also able to replicate the Dunlop-Tarsis observation, yielding very low hours-productivity and hours-wages correlations.

Variations in $\phi_g$ affect the dynamics of the model as follows: as $\phi_g$ increases, consumption decreases more whereas output, hours, investment, imports and exports increase less, thus leading to a smaller decrease in net exports. When $\phi_g = 1$ only consumption is affected and the rest of the variables remain unchanged.

### Model with Government Shocks and Imperfect Competition

The introduction of imperfect competition and increasing returns to scale modifies some of the results. It lowers the volatility of consumption, hours and productivity and raises that of output and investment. It increases the procyclicality of investment and therefore of imports and exports and even with $\phi_g = 1$ it produces countercyclical wages.

International comovements are perhaps the most affected by the introduction of imperfect competition, because all correlations increase, and now even imports and exports display positive correlations.

The dynamics of this model are displayed in Figure (2.5). Imperfect competition implies larger positive responses of hours, investment, output and imports. Exports do not decrease because in the foreign country the response of investment is also larger, and therefore imports in the foreign country go up. Hence, the effect of a government spending shock on net exports is smaller under imperfect competition.

Regarding the saving-investment correlation, the introduction of imperfect competition affects only output and investment, but not consumption. Therefore, for a given increase in government purchases investment grows more but so does output, boosting savings (and increasing the saving-investment correlation) and deteriorating less the balance of trade. Therefore, we can obtain high saving-investment correlations in a model with government shocks if we allow for imperfect competition.

Quantitatively speaking, imperfect competition amplifies the expansionary effect of government expenditure, almost doubling the response of all the variables, including net exports. Thus, the assumption of imperfect competition does not modify the qualitative implications of the model, but modifies the quantitative responses, a fact that may be important when analyzing the welfare implications of different fiscal policies.

The sensitivity of these results to variations in the scale parameter and in average markups can be seen in Figure (2.17). As in the case of technological shocks, variations in the scale parameter have no significant effect in any of the second moments. Variations in the degree of market power only affect the behaviour of productivity. For values of $\mu_{kn}$ smaller than 1.4 the correlation between productivity and output or hours is -1. However, this changes for values greater than 1.4, increasing as $\mu_{kn}$ increases and reaching values of +1 for $\mu_{kn}$ greater than 1.8.

### Model with Government shocks and Imperfect Competition with variable markups

If we let markups to be stochastic we obtain some interesting results. The volatility of output and consumption reach realistic levels, although hours and investment are a bit too volatile. Consumption and productivity are less countercyclical now, as are wages. We still obtain positive comovements across countries, with coefficients that now are lower and therefore closer to data. When $\phi_g = 1$ we also obtain output correlations that are larger than consumption correlations.

The dynamics of the model are a blend of the effect of variable markups and government shocks. The effect of variable markups dominate the dynamics, and therefore after the impact the countries are in a situation of recession, with a decrease in investment and hours due to the decrease in rates of return produced by the increased market power of firms. However, as we have seen before, the increase in government spending pushes up interest rates and therefore we have investment, hours and output decreasing less than in the case with only markup shocks. Likewise, consumption decreases more due to the negative wealth effect of government spending. All these movements improve the balance of trade, and thus generate a case in which an increase in government spending does not lead to a deterioration of the balance of trade.

Thus, the introduction of imperfect competition can improve the behaviour of models driven by government spending shocks in several ways. It modifies the dynamics of the model and produces interesting quantitative implications regarding the welfare effect of fiscal policies. We have also seen that these models confirm also the results obtained by Baxter (1992) and Kollmann (1992) in a one-good framework, being able to reproduce the situation of "twin deficits", a situation in which internal and external deficits coexist that was suffered recently by the U.S. This result is robust to the existence of increasing returns to scale and to the posibility of government affecting the utility of consumers. Only in the case in which markups are variable an increase in government purchases does not lead to an investment boom and therefore does not produce a deterioration of the balance of trade.

### A comparison between Permanent and Temporary Government shocks

An interesting issue to be analyzed is the distintion between temporary and permanent government spending shocks. This is based on the fact that in general government purchases have had both temporary and permanent components. The permanent component is generally associated with standard government expenditure whereas the temporary component is associated mainly with war expenditures (see Baxter and King (1993) for an analysis of the U.S. case and Baxter (1993) for an analysis in a one good model).

Our setup allows us to analyze the different behavior of the model in these two cases, defining the shocks as temporary when $\rho_g = 0.90$ [3] and permanent when $\rho_g = 0.99$ as in Baxter and King(1993).

In terms of second moments, we can see from Tables (2.9) and (2.10) that an increase in $\rho_g$ increases the volatility of investment and output. Domestic correlations remain unaltered, with the only exception of the correlation between saving and investment, which increases with $\rho_g$. Regarding international comovements, cross-country output, hours, productivity, wages, exports, imports correlations increase with $\rho_g$.

We can see in Figures (2.6) and (2.7) the differences in the dynamics of the two specifications (for $\phi_g = 0.2$). A permanent increase in government purchases creates a stronger wealth and interest rate effect, and therefore all the effects of the shock are amplified as $\rho_g$ increases. There is a higher increase after the shock in investment, hours, output and imports, whereas consumption decreases quite more. This also true for the foreign country, and therefore investment in the foreign country grows more, preventing exports in the home country from decreasing. However, imports grow more than exports decrease, and therefore the balance of trade deteriorates more as the shock becomes more persistent. Quantitatively speaking, with $\rho_g = 0.90$, a unitary increase in government purchases deteriorates the balance of trade by 0.05, whereas with $\rho_g = 0.99$ the deterioration is of 0.1.

The persistence of the shock also affects the behaviour of savings. In the case of temporary government shocks, savings decrease at the impact, whereas with permanent government shocks savings increase on impact. This happens because with a permanent increase in government spending there is a long run increase in interest rates that raises savings whereas a temporary increase just crowds them out. The behaviour of investment is similar to that of savings, with the difference that the imperfect substitution of goods prevents investment from declining after a temporary shock, thus creating a gap between saving and investment. Therefore, the saving-investment correlation is positively correlated with the degree of persistence of government shocks.

The presence of imperfect competition does not qualitatively alter the results. As we have stated before, it amplifies certain responses, in particular those of investment and therefore of net exports, but the main conclusions remain unaltered.

### Model with correlated government policies

The current world enviroment suggests that, even though in the past countries have not followed coordinated fiscal policies, it is quite likely that some coordination may arise among groups of countries like the European Union, Mercosur or Nafta. This has led us to make a first attempt to explore the implications of these kind of models when coordinated government spending shocks move the cycle. We have analyzed two levels of coordination, low coordination (corr(G,G*)=0.2) and high coordination (corr(G,G*)=0.6). Given the highly idiosyncratic nature of fiscal policy we do not believe that the levels of coordination will never reach values of correlation close to

[3] We have also experimented with $\rho_g = 0.5$ and the conclusions do not change.

one.

The second moments for these experiments appear in Table (2.11) and the dynamics in Figures (2.8) to (2.11). As the level of coordination increases, we can observe an amplification of the responses of investment, output, hours and consumption in both countries, mitigating the deterioration of the trade balance. This implies that in a framework of highly integrated countries uncoordinated fiscal expansions are likely to deteriorate the balance of trade of trading partners, although this could be avoided somehow through coordinated government policies. In addition, apart from the obvious effect of making international comovements more positive, we only observe an increase in output volatility and in the saving-investment correlation and a lowering of the volatility of foreign trade variables, which can be explained by the augmented degree of integration of the economies.

### 2.5.3 Model with both Technology and Government Shocks

Finally, after having seen the dynamics and implications of all these different sources of shocks and transmission mechanisms, we want to see how a model driven by both sources of shocks, technology and government spending, works. We can see the results of the simulations in Tables (2.12) to (2.14). In the case of perfect competition (model TG1), the model is similar to that of Ravn(1993) with the added feature of indivisible labor.

As we can see, the behaviour of the model is dominated by the technology shock, but we can note some improvement from the addition of government spending shocks. In particular, if we compare to model T1, we can see that the addition of government spending increases the volatility of consumption and productivity up to realistic levels. The major improvement can be seen in the domestic comovements, because the effect of the government shock is to lower the procyclicality of almost all domestic variables, solving to some extent what we called the "procyclicality puzzle".

It also does a good work, as was shown by Christiano and Eichenbaum (1992) for a closed economy, in solving the "labor market puzzle", driving down the correlation between hours and wages and productivity and almost equalizing the volatilities of labor and productivity. This is improved further with the addition of imperfect competition (Model TG2), and we can see that now productivity is more volatile than output and that the correlation between hours and productivy is even lower than in model T2 (an imperfectly competitive model with technology shock). Therefore, the combination of both types of shocks and the addition of imperfect competition is a good way of modelling the labor market in an open economy. However, the other two issues we were concerned with, international comovements and risk sharing, remain unexplained in this model.

The addition of variable markups (Model TGM1) adds little to the performance of the model (Table (2.17)), and even worsens its behaviour.

An interesting issue is to check what happens if we have correlated technology and government shocks. Some authors have argued that if it is true that the Solow residual is not orthogonal to government spending, technology and government shocks should be correlated in these models. We can see this kind of model in Tables (2.15) and (2.16), Model TG3. Again, we consider the cases of low correlation (corr(tech,gov)=0.2) and high correlation (corr(tech, gov)=0.6). We can see that almost nothing happens, and only small variations in the volatilities of output, consumption, labor, investment and productivity can be seen in the case of high correlation.

Finally, we have experimented with different specifications that included positive cross-country correlations of the markup processes combined with nationally correlated technology and markup process. The results, not reported here for reasons of space, did not improve in any way the behavior of the model and, if anything, the performance of the model worsened.

## 2.6 Conclusions

In this Chapter we have explored the implications of introducing imperfect competitions into models of international business cycles driven by technology and government shocks. By presenting some international evidence on markups we have demonstrated that imperfect competition is an issue to be taken into account at the international level. At a theoretical level we can conclude that the introduction of imperfect competition, can improve the behaviour of standard IBC model in several ways.

We have indentified five puzzles that a standard international business cycle model driven by technology disturbances leaves unexplained: volatility-foreign trade variables, procyclicality, labor market, risk sharing and international comovements. We have used these five issues as a guide for assesing the performance of the different models we have specified.

The main general effect of considering imperfect competition and increasing returns to scale is an amplification of the responses to the different shocks, which is generally robust to variations in the scale parameter, average markups and the parameters of the exogenous markup process. We have also seen that markup fluctuations alone are not able to reproduce the main stylized facts of international business cycles.

Specifically, we have seen that, in a standard model with technology shocks, imperfect competition can help in solving the labor market, procyclicality and comovement puzzles although the foreign trade and risk sharing puzzles are still present.

Regarding fiscal issues, we have confirmed some of the results already obtained in one-good models, as the ability of the model to replicate a situation of "twin deficits". We have also seen that high levels of saving-investment correlation are not a property of models driven by government shocks, although they can be obtained once we introduce imperfect competition.

We have also considered the case of coordinated government polices, and its implications for issues like the deterioration of the trade balance after a fiscal expansion. We have seen that a coordination of fiscal expansions can diminish the subsequent deterioration that is provoked in the trade balance of trading partners.

Finally, we have considered a model with a combination of supply (technology) and demand (government spending) shocks. We have seen that in combination with imperfect competition we can solve some of the problems of a standard model.

We conclude that imperfect competition seems to be a crucial characteristic to be included in models of international business cycles and although we have modelled it here exogenously, we think that further research should be directed at endogenizing markups and replicating the domestic and international stylized facts of imperfect competition. Some of the models presented in Rotemberg and Woodford (1992) or the model by Gali (1994) could be adapted to the open economy enviroment.

A second extension we think may be interesting would be to improve the modelling of the external sector by introducing imperfect competition also in foreign trade, perhaps along the lines of Dixit and Stiglitz (1977).

Table 2.1: International Real Wage correlations

| | Canada | France | U.K. | U.S. | Italy | Japan | Germany |
|---|---|---|---|---|---|---|---|
| Aus | 0.15 | 0.71 | 0.08 | -0.48 | 0.56 | 0.53 | 0.49 |
| | (0.23) | (0.15) | (0.26) | (0.21) | (0.15) | (0.16) | (0.17) |
| Can | | 0.57 | -0.18 | 0.39 | 0.44 | 0.22 | -0.11 |
| | | (0.14) | (0.24) | (0.24) | (0.18) | (0.23) | (0.22) |
| Fra | | | -0.19 | -0.15 | 0.84 | 0.50 | 0.29 |
| | | | (0.23) | (0.24) | (0.05) | (0.18) | (0.23) |
| U.K. | | | | -0.47 | -0.10 | 0.46 | 0.41 |
| | | | | (0.16) | (0.24) | (0.27) | (0.17) |
| Ita | | | | | -0.27 | -0.43 | -0.72 |
| | | | | | (0.26) | (0.23) | (0.07) |
| Jap | | | | | | 0.54 | 0.33 |
| | | | | | | (0.18) | (0.23) |
| Ger | | | | | | | 0.36 |
| | | | | | | | (0.20) |

Table 2.2: Domestic Labor Market Facts

| | Australia | Canada | France | U.K. | U.S. | Italy | Japan | Germany |
|---|---|---|---|---|---|---|---|---|
| Std(W) | 0.02 | 0.02 | 0.01 | 0.01 | 0.008 | 0.01 | 0.01 | 0.008 |
| Corr(Y,W) | -0.17 | -0.34 | -0.07 | 0.65 | 0.65 | -0.04 | 0.54 | -0.11 |
| | (0.17) | (0.20) | (0.29) | (0.18) | (0.10) | (0.05) | (0.16) | (0.18) |
| Corr(N,W) | -0.12 | -0.27 | -0.21 | 0.24 | 0.57 | -0.19 | 0.44 | 0.20 |
| | (0.21) | (0.19) | (0.31) | (0.23) | (0.14) | (0.13) | (0.14) | (0.17) |
| Corr(N,AP) | -0.87 | 0.20 | 0.47 | -0.76 | -0.19 | -0.87 | -0.56 | -0.98 |
| | (0.06) | (0.16) | (0.15) | (0.17) | (0.09) | (0.11) | (0.20) | (0.03) |

Notes: Data is quarterly from OECD Main Economic Indicators. The sample period is 1970:1 to 1993:4. Data is Hodrick-Prescott filtered and in logs. The variables are: W, real wage, Y, real output, N, total hours, AP, average productivity. Standard Errors computed using a Newey and West procedure are in parenthesis.

Table 2.3: Estimated Average Markup

| Canada | France | U.K. | U.S. | Italy | Japan | Germany |
|---|---|---|---|---|---|---|
| 1.34 | 1.37 | 1.42 | 1.53 | 1.56 | 1.41 | 1.32 |
| (0.03) | (0.11) | (0.09) | (0.12 ) | (0.15) | (0.08) | (0.10 ) |

Table 2.4: International Markup Correlations

| | Canada | France | U.K. | U.S. | Italy | Japan | Germany |
|---|---|---|---|---|---|---|---|
| Aus | 0.39 | -0.35 | 0.33 | 0.49 | 0.22 | 0.12 | -0.37 |
| | (0.11) | (0.11) | (0.11) | (0.12) | (0.12) | (0.17) | ( 0.15) |
| Can | | -0.54 | 0.28 | 0.80 | 0.28 | 0.15 | -0.50 |
| | | (0.12) | (0.16) | (0.10) | (0.11) | (0.21) | ( 0.14) |
| Fra | | | -0.49 | -0.52 | 0.35 | 0.02 | 0.35 |
| | | | (0.17) | (0.13) | (0.09) | (0.21) | (0.21) |
| UK | | | | 0.43 | 0.28 | 0.35 | -0.53 |
| | | | | (0.12) | (0.11) | (0.19) | (0.18) |
| US | | | | | 0.13 | 0.38 | -0.49 |
| | | | | | (0.09) | (0.19) | (0.14) |
| Ita | | | | | | 0.34 | 0.15 |
| | | | | | | (0.12) | (0.08) |
| Jap | | | | | | | 0.09 |
| | | | | | | | (0.21) |

Notes: Data is quarterly from OECD Main Economic Indicators. The sample period is 1979:1 to 1993:4. Data is Hodrick-Prescott filtered and in logs. Standard Errors computed using a Newey and West procedure are in parenthesis.

Table 2.5: Markups-HP filtered GNP Correlations

| | Aus | Can | Fra | UK | US | Ita | Jap | Ger |
|---|---|---|---|---|---|---|---|---|
| | | | | e=0.5 | | | | |
| $\mu$=1.2 | -0.48 | -0.36 | 0.07 | -0.45 | -0.94 | -0.41 | -0.69 | -0.14 |
| | (0.17) | (0.17) | (0.20) | (0.22) | (0.05) | (0.12) | (0.15) | (0.19) |
| $\mu$=1.4 | -0.57 | -0.63 | 0.06 | -0.47 | -0.95 | -0.37 | -0.74 | -0.22 |
| | (0.15) | (0.13) | (0.12) | (0.21) | (0.04) | (0.16) | (0.14) | (0.18) |
| $\mu$=1.6 | -0.64 | -0.79 | 0.05 | -0.49 | -0.96 | -0.41 | -0.77 | -0.31 |
| | (0.13) | (0.09) | (0.15) | (0.21) | (0.04) | (0.19) | (0.13) | (0.18) |
| $\mu$=1.8 | -0.68 | -0.88 | 0.04 | -0.51 | -0.96 | -0.43 | -0.79 | -0.40 |
| | (0.12) | (0.07) | (0.17) | (0.20) | (0.03) | (0.17) | (0.12) | (0.17) |
| | | | | e=1 | | | | |
| $\mu$=1.2 | -0.28 | 0.12 | 0.09 | -0.19 | -0.87 | -0.21 | -0.48 | -0.10 |
| | (0.18) | (0.18) | (0.12) | (0.24) | (0.07) | (0.20) | (0.18) | (0.19) |
| $\mu$=1.4 | -0.39 | -0.16 | 0.08 | -0.22 | -0.90 | -0.25 | -0.54 | -0.18 |
| | (0.17) | (0.16) | (0.11) | (0.23) | (0.06) | (0.16) | (0.17) | (0.18) |
| $\mu$=1.6 | -0.47 | -0.45 | 0.08 | -0.24 | -0.91 | -0.27 | -0.59 | -0.26 |
| | (0.15) | (0.14) | (0.13) | (0.23) | (0.05) | (0.12) | (0.16) | (0.18) |
| $\mu$=1.8 | -0.53 | -0.66 | 0.07 | -0.25 | -0.92 | -0.22 | -0.62 | -0.35 |
| | (0.14) | (0.10) | (0.20) | (0.23) | (0.04) | (0.20) | (0.15) | (0.17) |
| | | | | e=1.5 | | | | |
| $\mu$=1.2 | -0.20 | 0.28 | 0.09 | -0.09 | -0.83 | -0.11 | -0.38 | -0.09 |
| | (0.19) | (0.17) | (0.20) | (0.24) | (0.08) | (0.16) | (0.19) | (0.19) |
| $\mu$=1.4 | -0.32 | 0.05 | 0.09 | -0.12 | -0.87 | -0.17 | -0.45 | -0.16 |
| | (0.17) | (0.17) | (0.14) | (0.24) | (0.06) | (0.21) | (0.18) | (0.19) |
| $\mu$=1.6 | -0.41 | -0.23 | 0.08 | -0.14 | -0.89 | -0.19 | -0.49 | -0.25 |
| | (0.16) | (0.15) | (0.20) | (0.23) | (0.05) | (0.21) | (0.17) | (0.18) |
| $\mu$=1.8 | -0.47 | -0.49 | 0.08 | -0.15 | -0.90 | -0.18 | -0.53 | -0.34 |
| | (0.15) | (0.12) | (0.19) | (0.23) | (0.05) | (0.19) | (0.16) | (0.17) |
| | | | | e=2 | | | | |
| $\mu$=1.2 | -0.16 | 0.36 | 0.09 | -0.04 | -0.80 | -0.07 | -0.33 | -0.09 |
| | (0.19) | (0.17) | (0.10) | (0.24) | (0.08) | (0.12) | (0.20) | (0.19) |
| $\mu$=1.4 | -0.28 | 0.16 | 0.09 | -0.06 | -0.85 | -0.06 | -0.39 | -0.16 |
| | (0.18) | (0.16) | (0.12) | (0.24) | (0.07) | (0.21) | (0.19) | (0.19) |
| $\mu$=1.6 | -0.37 | -0.10 | 0.09 | -0.08 | -0.87 | -0.14 | -0.44 | -0.24 |
| | (0.16) | (0.15) | (0.15) | (0.24) | (0.06) | (0.21) | (0.18) | (0.18) |
| $\mu$=1.8 | -0.43 | -0.37 | 0.08 | -0.10 | -0.89 | -0.19 | -0.47 | -0.33 |
| | (0.15) | (0.13) | (0.12) | (0.23) | (0.05) | (0.11) | (0.17) | (0.18) |

Notes: Data is quarterly from OECD Main Economic Indicators. The sample period is 1979:1 to 1993:4. Data is Hodrick-Prescott filtered and in logs. Standard Errors computed using a Newey and West procedure are in parenthesis.

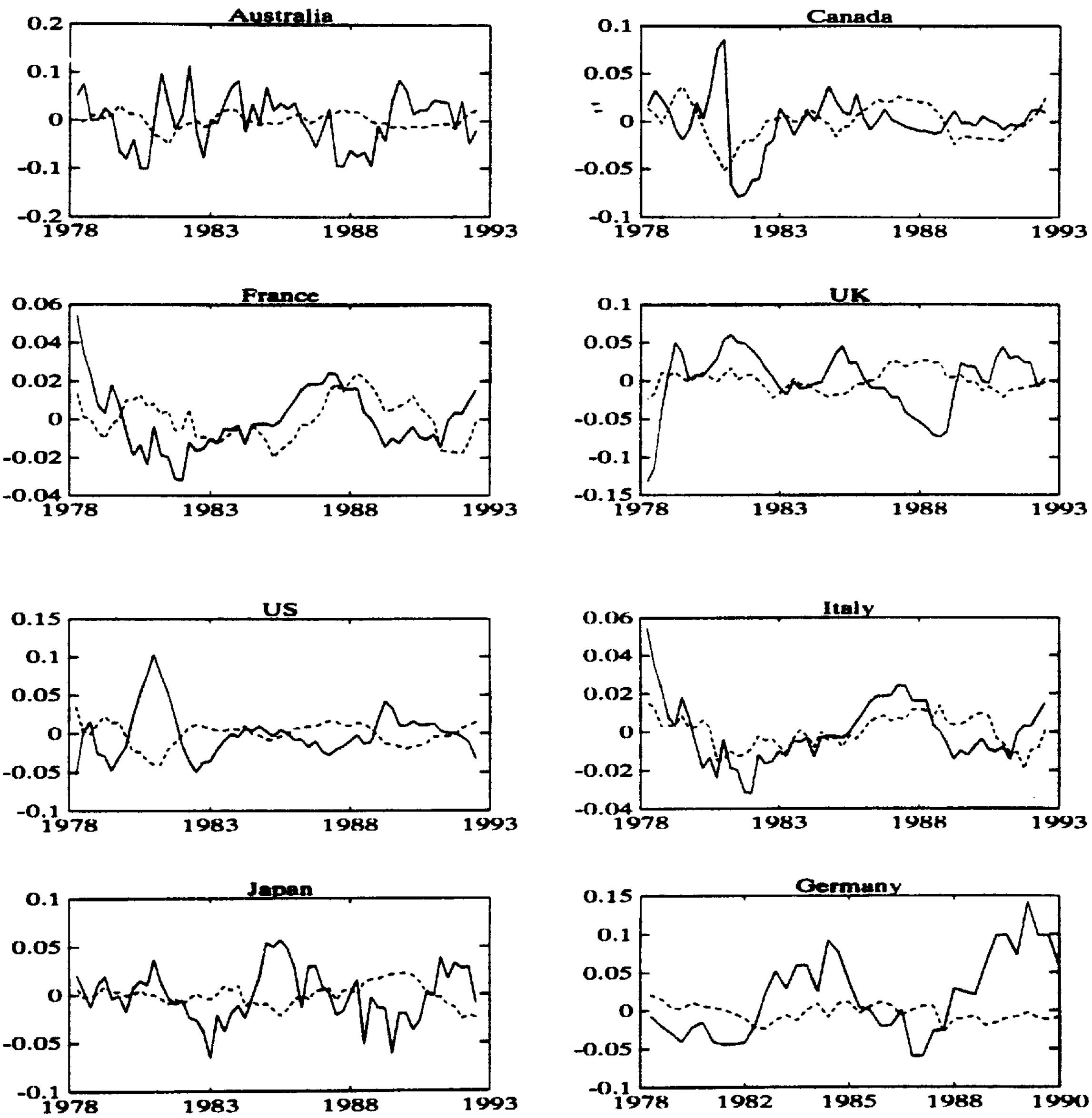


Figure 2.1: Markups(-) and HP filtered GNP (- -)

Table 2.6: Technological and/or Markup Shocks

| | S1 | | | | S2 | | | S3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | M1 | TM1 | T1 | T2 | TM1 | T1 | T2 | TM1 |
| STD(Y) | 1.48 | 2.05 | 1.63 | 2.57 | 1.47 | 2.04 | 2.56 | 1.40 | 1.87 | 2.45 |
| AR1(Y) | 0.61 | 0.60 | 0.67 | 0.61 | 0.61 | 0.60 | 0.61 | 0.61 | 0.60 | 0.62 |
| STD(C) | 0.16 | 0.16 | 0.15 | 0.16 | 0.16 | 0.17 | 0.17 | 0.24 | 0.26 | 0.22 |
| STD(N) | 0.69 | 0.49 | 1.10 | 0.79 | 0.69 | 0.48 | 0.79 | 0.64 | 0.44 | 0.80 |
| STD(AP) | 0.34 | 0.54 | 0.11 | 0.44 | 0.34 | 0.54 | 0.44 | 0.39 | 0.60 | 0.47 |
| STD(I) | 3.33 | 2.76 | 3.46 | 3.09 | 3.13 | 2.59 | 3.01 | 3.15 | 2.66 | 3.08 |
| STD(X) | 1.23 | 1.01 | 1.25 | 1.13 | 1.19 | 0.98 | 1.11 | 1.24 | 1.03 | 1.15 |
| STD(M) | 1.29 | 1.07 | 1.24 | 1.15 | 1.22 | 1.02 | 1.12 | 1.26 | 1.07 | 1.15 |
| STD(NX) | 0.45 | 0.37 | 0.40 | 0.39 | 0.39 | 0.33 | 0.37 | 0.42 | 0.37 | 0.39 |
| STD(TT) | 0.30 | 0.27 | 0.16 | 0.24 | 0.26 | 0.24 | 0.21 | 0.23 | 0.22 | 0.20 |
| CORR(C,Y) | 0.66 | 0.68 | -0.68 | 0.19 | 0.67 | 0.68 | 0.21 | 0.74 | 0.72 | 0.30 |
| CORR(N,Y) | 0.99 | 0.98 | 1.00 | 0.91 | 0.99 | 0.98 | 0.91 | 0.98 | 0.95 | 0.89 |
| CORR(AP,Y) | 0.94 | 0.98 | -0.87 | 0.66 | 0.94 | 0.98 | 0.65 | 0.94 | 0.97 | 0.62 |
| CORR(I,Y) | 0.95 | 0.95 | 0.97 | 0.95 | 0.95 | 0.95 | 0.95 | 0.94 | 0.92 | 0.93 |
| CORR(X,Y) | -0.08 | -0.08 | 0.18 | 0.02 | 0.15 | 0.15 | 0.14 | 0.08 | -0.04 | 0.04 |
| CORR(M,Y) | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| CORR(NX,Y) | -0.65 | -0.65 | -0.53 | -0.60 | -0.56 | -0.56 | -0.55 | -0.58 | -0.62 | -0.58 |
| CORR(TT,Y) | 0.47 | 0.50 | 0.30 | 0.42 | 0.41 | 0.44 | 0.37 | 0.36 | 0.41 | 0.35 |
| CORR(S,Y) | 1.00 | 0.99 | 1.00 | 0.98 | 1.00 | 0.99 | 0.98 | 0.99 | 0.98 | 0.97 |
| CORR(W,Y) | 0.58 | 0.62 | -0.49 | 0.25 | 0.68 | 0.84 | 0.43 | 0.76 | 0.84 | 0.45 |
| CORR(I,S) | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| CORR(TT,NX) | -0.39 | -0.41 | -0.28 | -0.35 | -0.38 | -0.41 | -0.34 | -0.34 | -0.36 | -0.31 |
| CORR(N,AP) | 0.88 | 0.92 | -0.89 | 0.29 | 0.88 | 0.91 | 0.28 | 0.86 | 0.84 | 0.20 |
| CORR(N,W) | 0.43 | 0.43 | -0.52 | -0.07 | 0.56 | 0.70 | 0.07 | 0.61 | 0.62 | 0.04 |
| CORR(Y,Y*) | 0.00 | -0.03 | 0.37 | 0.11 | 0.25 | 0.22 | 0.26 | 0.22 | 0.11 | 0.20 |
| CORR(C,C*) | 0.44 | 0.55 | 0.81 | 0.64 | 0.61 | 0.69 | 0.73 | 0.85 | 0.89 | 0.87 |
| CORR(I,I*) | -0.45 | -0.48 | -0.01 | -0.26 | -0.23 | -0.27 | -0.15 | -0.37 | -0.54 | -0.26 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.29 | -0.29 | -0.06 | -0.20 | -0.05 | -0.05 | -0.08 | -0.15 | -0.28 | -0.19 |
| CORR(M,M*) | -0.39 | -0.40 | -0.11 | -0.28 | -0.16 | -0.17 | -0.16 | -0.22 | -0.36 | -0.25 |
| CORR(AP,AP*) | -0.03 | 0.00 | 0.22 | 0.01 | 0.21 | 0.24 | 0.23 | 0.46 | 0.36 | 0.35 |
| CORR(N,N*) | 0.01 | -0.04 | 0.37 | 0.26 | 0.26 | 0.21 | 0.32 | 0.07 | -0.19 | 0.26 |
| CORR(W,W*) | 0.11 | 0.07 | 0.44 | 0.25 | 0.34 | 0.31 | 0.36 | 0.49 | 0.37 | 0.38 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.7: Government Shocks $\rho_g = 0.95$

| | G1 | | | | G2 | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ |
| STD(Y) | 0.13 | 0.10 | 0.04 | 0.00 | 0.24 | 0.18 | 0.08 | 0.00 |
| AR1(Y) | 0.68 | 0.68 | 0.68 | -0.10 | 0.68 | 0.68 | 0.68 | -0.08 |
| STD(C) | 0.98 | 1.46 | 4.22 | 100.00 | 0.63 | 0.90 | 2.48 | 100.00 |
| STD(N) | 1.56 | 1.56 | 1.56 | 0.98 | 1.12 | 1.12 | 1.12 | 0.54 |
| STD(AP) | 0.56 | 0.56 | 0.56 | 0.35 | 0.13 | 0.13 | 0.13 | 0.64 |
| STD(I) | 3.30 | 3.28 | 3.24 | 5.15 | 3.66 | 3.65 | 3.65 | 3.58 |
| STD(X) | 1.76 | 1.84 | 1.98 | 1.33 | 1.31 | 1.35 | 1.43 | 0.93 |
| STD(M) | 1.39 | 1.43 | 1.51 | 1.37 | 1.17 | 1.19 | 1.23 | 0.95 |
| STD(NX) | 0.54 | 0.58 | 0.64 | 0.50 | 0.33 | 0.36 | 0.40 | 0.35 |
| STD(TT) | 0.50 | 0.53 | 0.58 | 0.13 | 0.25 | 0.27 | 0.30 | 0.20 |
| CORR(C,Y) | -0.99 | -1.00 | -0.95 | -0.01 | -1.00 | -1.00 | -0.94 | -0.01 |
| CORR(N,Y) | 1.00 | 1.00 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 0.82 |
| CORR(AP,Y) | -1.00 | -1.00 | -1.00 | 0.22 | -0.99 | -0.99 | -0.99 | 0.87 |
| CORR(I,Y) | 0.99 | 0.99 | 0.99 | 0.96 | 1.00 | 1.00 | 1.00 | 0.17 |
| CORR(X,Y) | 0.32 | 0.27 | 0.20 | -0.18 | 0.59 | 0.55 | 0.48 | -0.04 |
| CORR(M,Y) | 0.86 | 0.85 | 0.84 | 0.96 | 0.93 | 0.93 | 0.91 | 0.13 |
| CORR(NX,Y) | -0.25 | -0.27 | -0.30 | -0.68 | -0.21 | -0.22 | -0.24 | -0.10 |
| CORR(TT,Y) | -0.25 | -0.27 | -0.30 | 0.34 | -0.21 | -0.22 | -0.24 | -0.15 |
| CORR(S,Y) | 0.72 | 0.69 | 0.62 | 1.00 | 0.92 | 0.91 | 0.88 | 0.16 |
| CORR(W,Y) | -1.00 | -1.00 | -1.00 | 0.44 | -1.00 | -1.00 | -1.00 | -0.20 |
| CORR(I,S) | 0.65 | 0.61 | 0.51 | 0.96 | 0.89 | 0.88 | 0.85 | 0.95 |
| CORR(TT,NX) | 1.00 | 1.00 | 1.00 | -0.36 | 1.00 | 1.00 | 1.00 | -0.09 |
| CORR(N,AP) | -1.00 | -1.00 | -1.00 | -0.13 | -1.00 | -0.99 | -0.99 | 0.43 |
| CORR(N,W) | -1.00 | -1.00 | -1.00 | 0.32 | -1.00 | -1.00 | -1.00 | -0.21 |
| CORR(Y,Y*) | 0.87 | 0.86 | 0.83 | 0.04 | 0.92 | 0.91 | 0.89 | 0.06 |
| CORR(C,C*) | 0.96 | 0.77 | 0.32 | 0.01 | 0.97 | 0.82 | 0.37 | 0.01 |
| CORR(I,I*) | 0.76 | 0.72 | 0.65 | -0.46 | 0.87 | 0.85 | 0.81 | -0.42 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.38 | -0.43 | -0.52 | -0.41 | 0.11 | 0.05 | -0.07 | -0.41 |
| CORR(M,M*) | -0.00 | -0.06 | -0.17 | -0.45 | 0.42 | 0.36 | 0.26 | -0.43 |
| CORR(AP,AP*) | 0.88 | 0.86 | 0.83 | -0.01 | 0.91 | 0.90 | 0.88 | -0.02 |
| CORR(N,N*) | 0.88 | 0.86 | 0.83 | 0.05 | 0.92 | 0.91 | 0.89 | 0.17 |
| CORR(W,W*) | 0.78 | 0.76 | 0.71 | 0.75 | 0.88 | 0.86 | 0.83 | 0.56 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.8: Model with Government Shocks and Imperfect Competition with Variable Markups - GM1

| | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ |
|---|---|---|---|---|
| STD(Y) | 1.51 | 1.50 | 1.49 | 1.49 |
| AR1(Y) | 0.67 | 0.67 | 0.67 | 0.67 |
| STD(C) | 0.17 | 0.18 | 0.21 | 0.25 |
| STD(N) | 1.12 | 1.12 | 1.12 | 1.12 |
| STD(AP) | 0.13 | 0.13 | 0.14 | 0.14 |
| STD(I) | 4.69 | 4.72 | 4.77 | 4.82 |
| STD(X) | 1.15 | 1.15 | 1.16 | 1.17 |
| STD(M) | 1.18 | 1.18 | 1.19 | 1.20 |
| STD(NX) | 0.35 | 0.35 | 0.36 | 0.36 |
| STD(TT) | 0.21 | 0.21 | 0.20 | 0.20 |
| CORR(C,Y) | -0.52 | -0.50 | -0.45 | -0.41 |
| CORR(N,Y) | 1.00 | 1.00 | 1.00 | 1.00 |
| CORR(AP,Y) | -0.90 | -0.90 | -0.89 | -0.89 |
| CORR(I,Y) | 0.97 | 0.97 | 0.98 | 0.98 |
| CORR(X,Y) | 0.29 | 0.28 | 0.27 | 0.25 |
| CORR(M,Y) | 0.97 | 0.97 | 0.97 | 0.97 |
| CORR(NX,Y) | -0.51 | -0.51 | -0.52 | -0.52 |
| CORR(TT,Y) | 0.39 | 0.40 | 0.40 | 0.40 |
| CORR(S,Y) | 0.99 | 1.00 | 1.00 | 1.00 |
| CORR(W,Y) | -0.36 | -0.35 | -0.35 | -0.35 |
| CORR(I,S) | 0.97 | 0.97 | 0.97 | 0.97 |
| CORR(TT,NX) | -0.45 | -0.46 | -0.48 | -0.48 |
| CORR(N,AP) | -0.92 | -0.92 | -0.91 | -0.91 |
| CORR(N,W) | -0.39 | -0.38 | -0.38 | -0.38 |
| CORR(Y,Y*) | 0.39 | 0.38 | 0.37 | 0.37 |
| CORR(C,C*) | 0.74 | 0.69 | 0.53 | 0.37 |
| CORR(I,I*) | 0.07 | 0.07 | 0.06 | 0.06 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | 0.11 | 0.10 | 0.09 | 0.07 |
| CORR(M,M*) | 0.00 | -0.01 | -0.03 | -0.04 |
| CORR(AP,AP*) | 0.23 | 0.22 | 0.21 | 0.20 |
| CORR(N,N*) | 0.40 | 0.39 | 0.38 | 0.37 |
| CORR(W,W*) | 0.49 | 0.48 | 0.46 | 0.46 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.9: Government Shocks $\rho_g = 0.90$

| | G1 | | | | G2 | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ |
| STD(Y) | 0.09 | 0.07 | 0.03 | 0.00 | 0.17 | 0.13 | 0.06 | 0.00 |
| AR1(Y) | 0.67 | 0.67 | 0.66 | -0.10 | 0.67 | 0.67 | 0.67 | -0.08 |
| STD(C) | 0.99 | 1.66 | 5.65 | 100.00 | 0.63 | 1.00 | 3.15 | 100.00 |
| STD(N) | 1.57 | 1.57 | 1.57 | 0.98 | 1.13 | 1.13 | 1.13 | 0.54 |
| STD(AP) | 0.58 | 0.58 | 0.58 | 0.35 | 0.13 | 0.13 | 0.14 | 0.64 |
| STD(I) | 2.12 | 2.01 | 1.83 | 5.15 | 3.11 | 3.06 | 2.97 | 3.58 |
| STD(X) | 1.96 | 2.05 | 2.22 | 1.33 | 1.40 | 1.44 | 1.53 | 0.93 |
| STD(M) | 1.49 | 1.54 | 1.64 | 1.37 | 1.21 | 1.24 | 1.29 | 0.95 |
| STD(NX) | 0.63 | 0.67 | 0.74 | 0.50 | 0.38 | 0.40 | 0.45 | 0.35 |
| STD(TT) | 0.58 | 0.61 | 0.68 | 0.13 | 0.29 | 0.31 | 0.34 | 0.20 |
| CORR(C,Y) | -0.99 | -0.99 | -0.95 | -0.01 | -0.99 | -0.99 | -0.93 | -0.01 |
| CORR(N,Y) | 1.00 | 1.00 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 0.82 |
| CORR(AP,Y) | -0.99 | -0.99 | -0.98 | 0.22 | -0.96 | -0.96 | -0.95 | 0.87 |
| CORR(I,Y) | 0.95 | 0.94 | 0.91 | 0.96 | 0.99 | 0.99 | 0.99 | 0.17 |
| CORR(X,Y) | 0.21 | 0.17 | 0.09 | -0.18 | 0.51 | 0.47 | 0.39 | -0.04 |
| CORR(M,Y) | 0.84 | 0.83 | 0.82 | 0.96 | 0.92 | 0.91 | 0.90 | 0.13 |
| CORR(NX,Y) | -0.29 | -0.31 | -0.34 | -0.68 | -0.23 | -0.25 | -0.27 | -0.10 |
| CORR(TT,Y) | -0.29 | -0.30 | -0.34 | 0.34 | -0.23 | -0.25 | -0.27 | -0.15 |
| CORR(S,Y) | 0.30 | 0.23 | 0.09 | 1.00 | 0.82 | 0.79 | 0.73 | 0.16 |
| CORR(W,Y) | -0.99 | -0.99 | -0.99 | 0.44 | -1.00 | -1.00 | -1.00 | -0.20 |
| CORR(I,S) | 0.35 | 0.27 | 0.12 | 0.96 | 0.82 | 0.79 | 0.73 | 0.95 |
| CORR(TT,NX) | 1.00 | 1.00 | 1.00 | -0.36 | 1.00 | 1.00 | 1.00 | -0.09 |
| CORR(N,AP) | -0.99 | -0.99 | -0.99 | -0.13 | -0.97 | -0.97 | -0.96 | 0.43 |
| CORR(N,W) | -1.00 | -1.00 | -1.00 | 0.32 | -1.00 | -1.00 | -1.00 | -0.21 |
| CORR(Y,Y*) | 0.84 | 0.82 | 0.78 | 0.04 | 0.90 | 0.88 | 0.86 | 0.06 |
| CORR(C,C*) | 0.95 | 0.67 | 0.23 | 0.01 | 0.97 | 0.75 | 0.28 | 0.01 |
| CORR(I,I*) | 0.84 | 0.80 | 0.72 | -0.46 | 0.89 | 0.87 | 0.83 | -0.42 |
| CORR(N,N*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.51 | -0.55 | -0.63 | -0.41 | -0.02 | -0.08 | -0.20 | -0.41 |
| CORR(M,M*) | -0.16 | -0.21 | -0.32 | -0.45 | 0.31 | 0.25 | 0.13 | -0.43 |
| CORR(AP,AP*) | 0.84 | 0.82 | 0.78 | -0.01 | 0.90 | 0.89 | 0.87 | -0.02 |
| CORR(N,N*) | 0.84 | 0.82 | 0.78 | 0.05 | 0.90 | 0.88 | 0.86 | 0.17 |
| CORR(W,W*) | 0.71 | 0.68 | 0.62 | 0.75 | 0.84 | 0.82 | 0.78 | 0.56 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.10: Government Shocks $\rho_g = 0.99$

| | G1 | | | | G2 | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ |
| STD(Y) | 0.21 | 0.16 | 0.07 | 0.00 | 0.34 | 0.25 | 0.11 | 0.00 |
| AR1(Y) | 0.68 | 0.68 | 0.68 | -0.10 | 0.68 | 0.68 | 0.68 | -0.08 |
| STD(C) | 0.99 | 1.31 | 3.07 | 100.00 | 0.64 | 0.83 | 1.94 | 100.00 |
| STD(N) | 1.56 | 1.56 | 1.56 | 0.98 | 1.13 | 1.13 | 1.13 | 0.54 |
| STD(AP) | 0.56 | 0.56 | 0.56 | 0.35 | 0.13 | 0.13 | 0.13 | 0.64 |
| STD(I) | 4.32 | 4.36 | 4.45 | 5.15 | 4.12 | 4.15 | 4.22 | 3.58 |
| STD(X) | 1.52 | 1.58 | 1.70 | 1.33 | 1.23 | 1.26 | 1.32 | 0.93 |
| STD(M) | 1.26 | 1.29 | 1.35 | 1.37 | 1.12 | 1.14 | 1.17 | 0.95 |
| STD(NX) | 0.43 | 0.46 | 0.51 | 0.50 | 0.28 | 0.30 | 0.33 | 0.35 |
| STD(TT) | 0.40 | 0.42 | 0.47 | 0.13 | 0.22 | 0.23 | 0.26 | 0.20 |
| CORR(C,Y) | -1.00 | -1.00 | -0.95 | -0.01 | -1.00 | -1.00 | -0.95 | -0.00 |
| CORR(N,Y) | 1.00 | 1.00 | 1.00 | 0.94 | 1.00 | 1.00 | 1.00 | 0.82 |
| CORR(AP,Y) | -1.00 | -1.00 | -1.00 | 0.22 | -0.98 | -0.98 | -0.97 | 0.87 |
| CORR(I,Y) | 0.99 | 0.99 | 0.99 | 0.96 | 1.00 | 1.00 | 0.99 | 0.17 |
| CORR(X,Y) | 0.47 | 0.43 | 0.35 | -0.18 | 0.68 | 0.65 | 0.59 | -0.04 |
| CORR(M,Y) | 0.89 | 0.88 | 0.87 | 0.96 | 0.95 | 0.94 | 0.93 | 0.13 |
| CORR(NX,Y) | -0.21 | -0.22 | -0.24 | -0.68 | -0.18 | -0.19 | -0.21 | -0.10 |
| CORR(TT,Y) | -0.20 | -0.21 | -0.24 | 0.34 | -0.17 | -0.18 | -0.20 | -0.15 |
| CORR(S,Y) | 0.91 | 0.90 | 0.88 | 1.00 | 0.96 | 0.96 | 0.95 | 0.16 |
| CORR(W,Y) | -1.00 | -1.00 | -1.00 | 0.44 | -1.00 | -1.00 | -1.00 | -0.20 |
| CORR(I,S) | 0.86 | 0.84 | 0.81 | 0.96 | 0.94 | 0.93 | 0.92 | 0.95 |
| CORR(TT,NX) | 1.00 | 1.00 | 1.00 | -0.36 | 0.99 | 0.99 | 0.99 | -0.09 |
| CORR(N,AP) | -1.00 | -1.00 | -1.00 | -0.13 | -0.98 | -0.98 | -0.98 | 0.43 |
| CORR(N,W) | -1.00 | -1.00 | -1.00 | 0.32 | -1.00 | -1.00 | -1.00 | -0.21 |
| CORR(Y,Y*) | 0.92 | 0.91 | 0.89 | 0.04 | 0.94 | 0.94 | 0.92 | 0.06 |
| CORR(C,C*) | 0.97 | 0.87 | 0.46 | 0.01 | 0.98 | 0.88 | 0.48 | 0.01 |
| CORR(I,I*) | 0.80 | 0.78 | 0.73 | -0.46 | 0.88 | 0.87 | 0.84 | -0.42 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.16 | -0.23 | -0.33 | -0.41 | 0.28 | 0.22 | 0.11 | -0.41 |
| CORR(M,M*) | 0.23 | 0.17 | 0.05 | -0.45 | 0.55 | 0.51 | 0.42 | -0.43 |
| CORR(AP,AP*) | 0.92 | 0.91 | 0.89 | -0.01 | 0.91 | 0.90 | 0.87 | -0.02 |
| CORR(N,N*) | 0.92 | 0.91 | 0.89 | 0.05 | 0.94 | 0.94 | 0.92 | 0.17 |
| CORR(W,W*) | 0.86 | 0.84 | 0.80 | 0.75 | 0.91 | 0.90 | 0.87 | 0.56 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.11: Model with Correlated Government Shocks ($\phi_g = 0.2$)

| | Corr(G,G*)=0.2 | | | | Corr(G,G*)=0.6 | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.99 | 0.90 | 0.99IC | 0.9IC | 0.99 | 0.90 | 0.99IC | 0.90IC |
| STD(Y) | 0.17 | 0.07 | 0.28 | 0.14 | 0.20 | 0.08 | 0.32 | 0.16 |
| AR1(Y) | 0.68 | 0.67 | 0.68 | 0.67 | 0.69 | 0.67 | 0.68 | 0.67 |
| STD(C) | 1.30 | 1.64 | 0.83 | 0.98 | 1.30 | 1.61 | 0.83 | 0.97 |
| STD(N) | 1.56 | 1.57 | 1.13 | 1.13 | 1.56 | 1.57 | 1.13 | 1.13 |
| STD(AP) | 0.56 | 0.58 | 0.13 | 0.13 | 0.56 | 0.58 | 0.13 | 0.13 |
| STD(I) | 4.31 | 2.01 | 4.13 | 3.06 | 4.25 | 2.01 | 4.10 | 3.05 |
| STD(X) | 1.42 | 1.79 | 1.18 | 1.31 | 1.18 | 1.36 | 1.07 | 1.13 |
| STD(M) | 1.20 | 1.39 | 1.09 | 1.17 | 1.08 | 1.17 | 1.04 | 1.07 |
| STD(NX) | 0.38 | 0.55 | 0.24 | 0.33 | 0.23 | 0.34 | 0.15 | 0.21 |
| STD(TT) | 0.35 | 0.51 | 0.19 | 0.25 | 0.21 | 0.32 | 0.12 | 0.16 |
| CORR(C,Y) | -1.00 | -0.99 | -1.00 | -0.99 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(N,Y) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| CORR(AP,Y) | -1.00 | -0.98 | -0.98 | -0.96 | -1.00 | -0.98 | -0.99 | -0.96 |
| CORR(I,Y) | 0.99 | 0.94 | 1.00 | 0.99 | 1.00 | 0.94 | 1.00 | 0.99 |
| CORR(X,Y) | 0.55 | 0.31 | 0.74 | 0.59 | 0.78 | 0.61 | 0.89 | 0.81 |
| CORR(M,Y) | 0.91 | 0.85 | 0.96 | 0.93 | 0.96 | 0.92 | 0.98 | 0.97 |
| CORR(NX,Y) | -0.18 | -0.25 | -0.15 | -0.20 | -0.11 | -0.16 | -0.10 | -0.13 |
| CORR(TT,Y) | -0.18 | -0.25 | -0.15 | -0.20 | -0.11 | -0.16 | -0.09 | -0.13 |
| CORR(S,Y) | 0.93 | 0.37 | 0.97 | 0.85 | 0.97 | 0.64 | 0.99 | 0.94 |
| CORR(W,Y) | -1.00 | -0.99 | -1.00 | -1.00 | -1.00 | -0.99 | -1.00 | -1.00 |
| CORR(I,S) | 0.89 | 0.41 | 0.96 | 0.86 | 0.96 | 0.69 | 0.98 | 0.94 |
| CORR(TT,NX) | 1.00 | 1.00 | 0.99 | 1.00 | 1.00 | 1.00 | 0.99 | 1.00 |
| CORR(N,AP) | -1.00 | -0.99 | -0.98 | -0.97 | -1.00 | -0.99 | -0.99 | -0.97 |
| CORR(N,W) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(Y,Y*) | 0.94 | 0.87 | 0.96 | 0.92 | 0.98 | 0.95 | 0.98 | 0.97 |
| CORR(C,C*) | 0.91 | 0.77 | 0.92 | 0.82 | 0.97 | 0.91 | 0.97 | 0.93 |
| CORR(I,I*) | 0.85 | 0.87 | 0.91 | 0.91 | 0.94 | 0.95 | 0.97 | 0.97 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.03 | -0.40 | 0.41 | 0.12 | 0.43 | 0.07 | 0.73 | 0.54 |
| CORR(M,M*) | 0.36 | -0.02 | 0.64 | 0.42 | 0.70 | 0.44 | 0.85 | 0.74 |
| CORR(AP,AP*) | 0.94 | 0.87 | 0.93 | 0.93 | 0.98 | 0.95 | 0.97 | 0.97 |
| CORR(N,N*) | 0.94 | 0.87 | 0.96 | 0.92 | 0.98 | 0.95 | 0.98 | 0.97 |
| CORR(W,W*) | 0.89 | 0.78 | 0.93 | 0.88 | 0.96 | 0.91 | 0.97 | 0.95 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient. IC marks the models with Imperfect Competition.

Table 2.12: Technological and Government Shocks (S1)

| | TG1(S1) | | | | TG2(S1) | | | |
|---|---|---|---|---|---|---|---|---|
| | $\varphi_g = 0$ | $\varphi_g = 0.2$ | $\varphi_g = 0.6$ | $\varphi_g = 1$ | $\varphi_g = 0$ | $\varphi_g = 0.2$ | $\varphi_g = 0.6$ | $\varphi_g = 1$ |
| STD(Y) | 1.35 | 1.36 | 1.39 | 1.42 | 1.82 | 1.85 | 1.90 | 1.95 |
| AR1(Y) | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| STD(C) | 0.29 | 0.29 | 0.30 | 0.31 | 0.28 | 0.28 | 0.27 | 0.27 |
| STD(N) | 0.63 | 0.63 | 0.64 | 0.65 | 0.46 | 0.45 | 0.46 | 0.47 |
| STD(AP) | 0.44 | 0.43 | 0.40 | 0.38 | 0.61 | 0.60 | 0.58 | 0.56 |
| STD(I) | 4.41 | 4.41 | 4.40 | 4.40 | 3.63 | 3.61 | 3.60 | 3.59 |
| STD(X) | 1.12 | 1.12 | 1.12 | 1.12 | 0.91 | 0.91 | 0.91 | 0.91 |
| STD(M) | 1.22 | 1.21 | 1.21 | 1.21 | 0.99 | 0.99 | 0.99 | 0.99 |
| STD(NX) | 0.41 | 0.40 | 0.40 | 0.40 | 0.33 | 0.33 | 0.32 | 0.32 |
| STD(TT) | 0.42 | 0.41 | 0.39 | 0.38 | 0.37 | 0.36 | 0.35 | 0.33 |
| CORR(C,Y) | 0.63 | 0.64 | 0.63 | 0.61 | 0.60 | 0.62 | 0.65 | 0.65 |
| CORR(N,Y) | 0.95 | 0.96 | 0.98 | 0.98 | 0.91 | 0.93 | 0.96 | 0.97 |
| CORR(AP,Y) | 0.91 | 0.92 | 0.94 | 0.94 | 0.95 | 0.96 | 0.97 | 0.98 |
| CORR(I,Y) | 0.94 | 0.94 | 0.95 | 0.95 | 0.93 | 0.93 | 0.94 | 0.94 |
| CORR(X,Y) | -0.01 | 0.00 | 0.03 | 0.04 | -0.03 | -0.01 | 0.03 | 0.06 |
| CORR(M,Y) | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| CORR(NX,Y) | -0.64 | -0.63 | -0.63 | -0.62 | -0.64 | -0.64 | -0.63 | -0.62 |
| CORR(TT,Y) | 0.55 | 0.55 | 0.54 | 0.53 | 0.58 | 0.57 | 0.56 | 0.55 |
| CORR(S,Y) | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.98 | 0.98 | 0.99 |
| CORR(W,Y) | 0.70 | 0.73 | 0.76 | 0.76 | 0.77 | 0.81 | 0.85 | 0.86 |
| CORR(I,S) | 0.96 | 0.96 | 0.96 | 0.96 | 0.95 | 0.95 | 0.96 | 0.96 |
| CORR(TT,NX) | -0.39 | -0.40 | -0.42 | -0.43 | -0.38 | -0.40 | -0.41 | -0.43 |
| CORR(N,AP) | 0.74 | 0.79 | 0.84 | 0.86 | 0.74 | 0.80 | 0.87 | 0.90 |
| CORR(N,W) | 0.45 | 0.52 | 0.60 | 0.61 | 0.45 | 0.55 | 0.67 | 0.72 |
| CORR(Y,Y*) | -0.07 | -0.05 | -0.01 | 0.01 | -0.12 | -0.09 | -0.04 | 0.00 |
| CORR(C,C*) | 0.68 | 0.62 | 0.47 | 0.30 | 0.73 | 0.68 | 0.54 | 0.39 |
| CORR(I,I*) | -0.48 | -0.46 | -0.43 | -0.40 | -0.53 | -0.51 | -0.45 | -0.41 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.21 | -0.19 | -0.16 | -0.14 | -0.25 | -0.22 | -0.16 | -0.12 |
| CORR(M,M*) | -0.36 | -0.35 | -0.32 | -0.30 | -0.41 | -0.38 | -0.33 | -0.30 |
| CORR(AP,AP*) | 0.09 | 0.05 | -0.01 | -0.06 | 0.02 | 0.01 | -0.01 | -0.02 |
| CORR(N,N*) | -0.07 | -0.05 | 0.00 | 0.05 | -0.10 | -0.09 | -0.04 | 0.04 |
| CORR(W,W*) | 0.07 | 0.09 | 0.12 | 0.15 | 0.00 | 0.03 | 0.08 | 0.13 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.13: Technological and Government Shocks (S2)

| | TG1(S2) | | | | TG2(S2) | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ |
| STD(Y) | 1.33 | 1.35 | 1.39 | 1.42 | 1.78 | 1.82 | 1.89 | 1.95 |
| AR1(Y) | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| STD(C) | 0.32 | 0.31 | 0.31 | 0.32 | 0.31 | 0.30 | 0.29 | 0.29 |
| STD(N) | 0.62 | 0.63 | 0.64 | 0.65 | 0.45 | 0.45 | 0.45 | 0.47 |
| STD(AP) | 0.45 | 0.43 | 0.40 | 0.38 | 0.63 | 0.61 | 0.58 | 0.56 |
| STD(I) | 4.17 | 4.16 | 4.16 | 4.16 | 3.43 | 3.41 | 3.40 | 3.40 |
| STD(X) | 1.11 | 1.10 | 1.10 | 1.10 | 0.90 | 0.90 | 0.90 | 0.90 |
| STD(M) | 1.17 | 1.17 | 1.16 | 1.16 | 0.96 | 0.95 | 0.95 | 0.95 |
| STD(NX) | 0.36 | 0.35 | 0.35 | 0.34 | 0.30 | 0.29 | 0.28 | 0.28 |
| STD(TT) | 0.37 | 0.36 | 0.34 | 0.33 | 0.33 | 0.32 | 0.31 | 0.29 |
| CORR(C,Y) | 0.65 | 0.65 | 0.64 | 0.62 | 0.61 | 0.63 | 0.66 | 0.66 |
| CORR(N,Y) | 0.95 | 0.96 | 0.98 | 0.98 | 0.90 | 0.92 | 0.96 | 0.97 |
| CORR(AP,Y) | 0.90 | 0.92 | 0.94 | 0.94 | 0.95 | 0.96 | 0.97 | 0.98 |
| CORR(I,Y) | 0.94 | 0.95 | 0.95 | 0.95 | 0.93 | 0.93 | 0.94 | 0.94 |
| CORR(X,Y) | 0.21 | 0.22 | 0.25 | 0.26 | 0.18 | 0.20 | 0.24 | 0.28 |
| CORR(M,Y) | 0.96 | 0.97 | 0.97 | 0.97 | 0.96 | 0.96 | 0.97 | 0.97 |
| CORR(NX,Y) | -0.55 | -0.55 | -0.54 | -0.53 | -0.56 | -0.56 | -0.54 | -0.53 |
| CORR(TT,Y) | 0.48 | 0.47 | 0.47 | 0.46 | 0.51 | 0.50 | 0.48 | 0.47 |
| CORR(S,Y) | 0.99 | 0.99 | 0.99 | 0.99 | 0.97 | 0.98 | 0.98 | 0.99 |
| CORR(W,Y) | 0.70 | 0.73 | 0.75 | 0.75 | 0.77 | 0.80 | 0.84 | 0.86 |
| CORR(I,S) | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| CORR(TT,NX) | -0.38 | -0.40 | -0.42 | -0.43 | -0.38 | -0.39 | -0.41 | -0.42 |
| CORR(N,AP) | 0.72 | 0.78 | 0.84 | 0.86 | 0.71 | 0.78 | 0.86 | 0.90 |
| CORR(N,W) | 0.44 | 0.51 | 0.59 | 0.61 | 0.41 | 0.52 | 0.65 | 0.71 |
| CORR(Y,Y*) | 0.18 | 0.20 | 0.23 | 0.26 | 0.12 | 0.15 | 0.20 | 0.24 |
| CORR(C,C*) | 0.79 | 0.74 | 0.60 | 0.43 | 0.82 | 0.78 | 0.67 | 0.53 |
| CORR(I,I*) | -0.28 | -0.25 | -0.21 | -0.18 | -0.34 | -0.31 | -0.24 | -0.18 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | 0.03 | 0.05 | 0.08 | 0.10 | -0.02 | 0.02 | 0.08 | 0.12 |
| CORR(M,M*) | -0.14 | -0.12 | -0.09 | -0.07 | -0.19 | -0.16 | -0.10 | -0.06 |
| CORR(AP,AP*) | 0.32 | 0.28 | 0.23 | 0.18 | 0.26 | 0.25 | 0.24 | 0.23 |
| CORR(N,N*) | 0.16 | 0.19 | 0.24 | 0.29 | 0.12 | 0.14 | 0.20 | 0.28 |
| CORR(W,W*) | 0.31 | 0.32 | 0.36 | 0.38 | 0.24 | 0.27 | 0.32 | 0.36 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.14: Technological and Government Shocks (S3)

| | TG1(S3) | | | | TG2(S3) | | | |
|---|---|---|---|---|---|---|---|---|
| | $\varphi_g = 0$ | $\varphi_g = 0.2$ | $\varphi_g = 0.6$ | $\varphi_g = 1$ | $\varphi_g = 0$ | $\varphi_g = 0.2$ | $\varphi_g = 0.6$ | $\varphi_g = 1$ |
| STD(Y) | 1.20 | 1.23 | 1.29 | 1.35 | 1.55 | 1.60 | 1.71 | 1.81 |
| AR1(Y) | 0.60 | 0.60 | 0.61 | 0.61 | 0.59 | 0.59 | 0.60 | 0.61 |
| STD(C) | 0.50 | 0.48 | 0.44 | 0.42 | 0.49 | 0.47 | 0.42 | 0.39 |
| STD(N) | 0.57 | 0.57 | 0.58 | 0.61 | 0.45 | 0.42 | 0.41 | 0.42 |
| STD(AP) | 0.58 | 0.54 | 0.48 | 0.43 | 0.75 | 0.72 | 0.66 | 0.62 |
| STD(I) | 4.36 | 4.31 | 4.25 | 4.22 | 3.76 | 3.66 | 3.55 | 3.50 |
| STD(X) | 1.20 | 1.19 | 1.17 | 1.16 | 0.98 | 0.97 | 0.96 | 0.95 |
| STD(M) | 1.26 | 1.25 | 1.23 | 1.22 | 1.04 | 1.03 | 1.01 | 1.00 |
| STD(NX) | 0.43 | 0.42 | 0.40 | 0.39 | 0.38 | 0.37 | 0.35 | 0.33 |
| STD(TT) | 0.35 | 0.33 | 0.31 | 0.29 | 0.33 | 0.31 | 0.29 | 0.27 |
| CORR(C,Y) | 0.67 | 0.69 | 0.71 | 0.70 | 0.59 | 0.64 | 0.69 | 0.72 |
| CORR(N,Y) | 0.87 | 0.91 | 0.95 | 0.97 | 0.71 | 0.79 | 0.90 | 0.94 |
| CORR(AP,Y) | 0.87 | 0.90 | 0.93 | 0.95 | 0.91 | 0.93 | 0.96 | 0.97 |
| CORR(I,Y) | 0.91 | 0.91 | 0.92 | 0.93 | 0.86 | 0.87 | 0.89 | 0.91 |
| CORR(X,Y) | -0.02 | 0.03 | 0.09 | 0.14 | -0.19 | -0.12 | -0.01 | 0.08 |
| CORR(M,Y) | 0.96 | 0.96 | 0.96 | 0.97 | 0.95 | 0.95 | 0.96 | 0.96 |
| CORR(NX,Y) | -0.63 | -0.61 | -0.59 | -0.57 | -0.68 | -0.65 | -0.62 | -0.59 |
| CORR(TT,Y) | 0.46 | 0.45 | 0.43 | 0.42 | 0.52 | 0.50 | 0.47 | 0.45 |
| CORR(S,Y) | 0.96 | 0.97 | 0.98 | 0.98 | 0.91 | 0.93 | 0.95 | 0.97 |
| CORR(W,Y) | 0.72 | 0.75 | 0.80 | 0.81 | 0.72 | 0.77 | 0.84 | 0.87 |
| CORR(I,S) | 0.95 | 0.96 | 0.96 | 0.96 | 0.95 | 0.95 | 0.96 | 0.96 |
| CORR(TT,NX) | -0.34 | -0.35 | -0.37 | -0.39 | -0.34 | -0.35 | -0.37 | -0.38 |
| CORR(N,AP) | 0.52 | 0.64 | 0.78 | 0.84 | 0.35 | 0.52 | 0.74 | 0.85 |
| CORR(N,W) | 0.28 | 0.41 | 0.58 | 0.65 | 0.03 | 0.22 | 0.51 | 0.66 |
| CORR(Y,Y*) | 0.03 | 0.08 | 0.16 | 0.21 | -0.14 | -0.06 | 0.06 | 0.15 |
| CORR(C,C*) | 0.92 | 0.90 | 0.82 | 0.69 | 0.93 | 0.91 | 0.85 | 0.76 |
| CORR(I,I*) | -0.60 | -0.55 | -0.46 | -0.38 | -0.76 | -0.72 | -0.61 | -0.50 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.24 | -0.19 | -0.10 | -0.05 | -0.46 | -0.38 | -0.25 | -0.14 |
| CORR(M,M*) | -0.34 | -0.30 | -0.22 | -0.17 | -0.55 | -0.48 | -0.36 | -0.26 |
| CORR(AP,AP*) | 0.59 | 0.55 | 0.49 | 0.44 | 0.40 | 0.39 | 0.37 | 0.35 |
| CORR(N,N*) | -0.34 | -0.28 | -0.11 | 0.04 | -0.33 | -0.41 | -0.33 | -0.13 |
| CORR(W,W*) | 0.34 | 0.38 | 0.45 | 0.50 | 0.11 | 0.19 | 0.33 | 0.42 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.15: Model with Correlated Technology and Government Shocks (Corr=0.2)

| | TG3(S3) | | | | TG3(S3)IC | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ | $\phi_g = 0$ | $\phi_g = 0.2$ | $\phi_g = 0.6$ | $\phi_g = 1$ |
| STD(Y) | 1.22 | 1.25 | 1.30 | 1.35 | 1.58 | 1.63 | 1.73 | 1.81 |
| AR1(Y) | 0.60 | 0.60 | 0.61 | 0.61 | 0.59 | 0.60 | 0.60 | 0.61 |
| STD(C) | 0.47 | 0.45 | 0.42 | 0.40 | 0.47 | 0.44 | 0.40 | 0.37 |
| STD(N) | 0.57 | 0.57 | 0.59 | 0.61 | 0.45 | 0.42 | 0.41 | 0.42 |
| STD(AP) | 0.56 | 0.53 | 0.47 | 0.43 | 0.73 | 0.70 | 0.65 | 0.62 |
| STD(I) | 4.33 | 4.29 | 4.24 | 4.22 | 3.72 | 3.64 | 3.54 | 3.50 |
| STD(X) | 1.20 | 1.19 | 1.18 | 1.16 | 0.98 | 0.97 | 0.96 | 0.95 |
| STD(M) | 1.26 | 1.25 | 1.23 | 1.22 | 1.05 | 1.03 | 1.01 | 1.00 |
| STD(NX) | 0.43 | 0.42 | 0.40 | 0.39 | 0.38 | 0.37 | 0.35 | 0.33 |
| STD(TT) | 0.33 | 0.32 | 0.30 | 0.29 | 0.31 | 0.30 | 0.28 | 0.27 |
| CORR(C,Y) | 0.67 | 0.69 | 0.69 | 0.67 | 0.60 | 0.64 | 0.68 | 0.69 |
| CORR(N,Y) | 0.88 | 0.92 | 0.96 | 0.97 | 0.74 | 0.81 | 0.90 | 0.94 |
| CORR(AP,Y) | 0.88 | 0.90 | 0.93 | 0.95 | 0.91 | 0.94 | 0.96 | 0.97 |
| CORR(I,Y) | 0.91 | 0.91 | 0.92 | 0.93 | 0.87 | 0.88 | 0.89 | 0.91 |
| CORR(X,Y) | -0.02 | 0.02 | 0.09 | 0.14 | -0.18 | -0.11 | -0.01 | 0.08 |
| CORR(M,Y) | 0.96 | 0.96 | 0.96 | 0.97 | 0.95 | 0.95 | 0.96 | 0.96 |
| CORR(NX,Y) | -0.63 | -0.61 | -0.59 | -0.57 | -0.67 | -0.65 | -0.62 | -0.59 |
| CORR(TT,Y) | 0.45 | 0.45 | 0.43 | 0.42 | 0.51 | 0.49 | 0.47 | 0.45 |
| CORR(S,Y) | 0.97 | 0.97 | 0.98 | 0.98 | 0.92 | 0.93 | 0.95 | 0.97 |
| CORR(W,Y) | 0.72 | 0.75 | 0.79 | 0.81 | 0.73 | 0.78 | 0.84 | 0.87 |
| CORR(I,S) | 0.96 | 0.96 | 0.96 | 0.96 | 0.95 | 0.96 | 0.96 | 0.96 |
| CORR(TT,NX) | -0.35 | -0.36 | -0.38 | -0.39 | -0.35 | -0.36 | -0.37 | -0.50 |
| CORR(N,AP) | 0.56 | 0.66 | 0.79 | 0.84 | 0.41 | 0.56 | 0.75 | 0.80 |
| CORR(N,W) | 0.32 | 0.44 | 0.58 | 0.65 | 0.09 | 0.27 | 0.53 | 0.66 |
| CORR(Y,Y*) | 0.04 | 0.09 | 0.16 | 0.21 | -0.11 | -0.04 | 0.07 | 0.15 |
| CORR(C,C*) | 0.92 | 0.91 | 0.84 | 0.73 | 0.93 | 0.92 | 0.87 | 0.79 |
| CORR(I,I*) | -0.59 | -0.54 | -0.45 | -0.38 | -0.75 | -0.71 | -0.61 | -0.50 |
| CORR(NX,NX) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.23 | -0.18 | -0.11 | -0.05 | -0.44 | -0.37 | -0.24 | -0.14 |
| CORR(M,M*) | -0.33 | -0.29 | -0.22 | -0.17 | -0.53 | -0.47 | -0.36 | -0.26 |
| CORR(AP,AP*) | 0.58 | 0.55 | 0.49 | 0.44 | 0.40 | 0.39 | 0.37 | 0.35 |
| CORR(N,N*) | -0.31 | -0.25 | -0.10 | 0.04 | -0.36 | -0.41 | -0.31 | -0.13 |
| CORR(W,W*) | 0.35 | 0.39 | 0.45 | 0.50 | 0.14 | 0.21 | 0.33 | 0.42 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.16: Model with Correlated Technology and Government Shocks (Corr=0.6)

| | TG3(S3) | | | | TG3(S3)IC | | | |
|---|---|---|---|---|---|---|---|---|
| | $\varphi_g = 0$ | $\varphi_g = 0.2$ | $\varphi_g = 0.6$ | $\varphi_g = 1$ | $\varphi_g = 0$ | $\varphi_g = 0.2$ | $\varphi_g = 0.6$ | $\varphi_g = 1$ |
| STD(Y) | 1.26 | 1.28 | 1.32 | 1.35 | 1.64 | 1.68 | 1.75 | 1.81 |
| AR1(Y) | 0.60 | 0.61 | 0.61 | 0.61 | 0.60 | 0.60 | 0.60 | 0.61 |
| STD(C) | 0.42 | 0.40 | 0.37 | 0.34 | 0.41 | 0.39 | 0.36 | 0.33 |
| STD(N) | 0.58 | 0.58 | 0.59 | 0.61 | 0.43 | 0.42 | 0.42 | 0.42 |
| STD(AP) | 0.52 | 0.50 | 0.46 | 0.43 | 0.70 | 0.68 | 0.64 | 0.62 |
| STD(I) | 4.27 | 4.25 | 4.23 | 4.22 | 3.65 | 3.60 | 3.53 | 3.50 |
| STD(X) | 1.22 | 1.20 | 1.18 | 1.16 | 0.99 | 0.98 | 0.96 | 0.95 |
| STD(M) | 1.27 | 1.26 | 1.23 | 1.22 | 1.05 | 1.04 | 1.02 | 1.00 |
| STD(NX) | 0.43 | 0.42 | 0.40 | 0.39 | 0.38 | 0.37 | 0.35 | 0.33 |
| STD(TT) | 0.29 | 0.29 | 0.29 | 0.29 | 0.28 | 0.28 | 0.27 | 0.27 |
| CORR(C,Y) | 0.69 | 0.68 | 0.64 | 0.58 | 0.63 | 0.65 | 0.65 | 0.63 |
| CORR(N,Y) | 0.92 | 0.94 | 0.96 | 0.97 | 0.81 | 0.85 | 0.91 | 0.94 |
| CORR(AP,Y) | 0.90 | 0.91 | 0.94 | 0.95 | 0.93 | 0.95 | 0.97 | 0.97 |
| CORR(I,Y) | 0.91 | 0.92 | 0.92 | 0.93 | 0.87 | 0.88 | 0.90 | 0.91 |
| CORR(X,Y) | -0.01 | 0.02 | 0.09 | 0.14 | -0.15 | -0.10 | -0.00 | 0.08 |
| CORR(M,Y) | 0.96 | 0.96 | 0.96 | 0.97 | 0.95 | 0.95 | 0.96 | 0.96 |
| CORR(NX,Y) | -0.63 | -0.61 | -0.59 | -0.57 | -0.67 | -0.65 | -0.62 | -0.59 |
| CORR(TT,Y) | 0.44 | 0.43 | 0.43 | 0.42 | 0.49 | 0.48 | 0.46 | 0.45 |
| CORR(S,Y) | 0.97 | 0.98 | 0.98 | 0.98 | 0.93 | 0.94 | 0.96 | 0.97 |
| CORR(W,Y) | 0.73 | 0.76 | 0.79 | 0.81 | 0.76 | 0.80 | 0.84 | 0.87 |
| CORR(I,S) | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| CORR(TT,NX) | -0.38 | -0.39 | -0.39 | -0.39 | -0.38 | -0.38 | -0.38 | -0.38 |
| CORR(N,AP) | 0.65 | 0.72 | 0.80 | 0.84 | 0.54 | 0.64 | 0.78 | 0.85 |
| CORR(N,W) | 0.40 | 0.49 | 0.60 | 0.65 | 0.23 | 0.37 | 0.56 | 0.66 |
| CORR(Y,Y*) | 0.08 | 0.11 | 0.17 | 0.21 | -0.06 | -0.01 | 0.08 | 0.15 |
| CORR(C,C*) | 0.92 | 0.93 | 0.90 | 0.83 | 0.92 | 0.93 | 0.92 | 0.88 |
| CORR(I,I*) | -0.57 | -0.52 | -0.45 | -0.38 | -0.72 | -0.68 | -0.59 | -0.50 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| CORR(X,X*) | -0.22 | -0.18 | -0.11 | -0.05 | -0.40 | -0.34 | -0.23 | -0.14 |
| CORR(M,M*) | -0.32 | -0.29 | -0.22 | -0.17 | -0.50 | -0.44 | -0.35 | -0.26 |
| CORR(AP,AP*) | 0.57 | 0.54 | 0.49 | 0.44 | 0.39 | 0.38 | 0.37 | 0.35 |
| CORR(N,N*) | -0.26 | -0.20 | -0.07 | 0.04 | -0.40 | -0.40 | -0.28 | -0.13 |
| CORR(W,W*) | 0.37 | 0.41 | 0.46 | 0.50 | 0.19 | 0.25 | 0.35 | 0.42 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient.

Table 2.17: Technological, Markup and Government Shocks

| | TGM1(S1) | | | | TGM1(S2) | | | | TGM1(S3) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0.2 | 0.6 | 1 | 0 | 0.2 | 0.6 | 1 | 0 | 0.2 | 0.6 | 1 |
| STD(Y) | 2.30 | 2.32 | 2.37 | 2.41 | 2.27 | 1.02 | 2.35 | 2.40 | 2.11 | 1.11 | 2.23 | 2.3 |
| AR1(Y) | 0.62 | 0.62 | 0.61 | 0.61 | 0.62 | 0.70 | 0.61 | 0.61 | 0.62 | 0.70 | 0.62 | 0.6 |
| STD(C) | 0.24 | 0.24 | 0.25 | 0.25 | 0.26 | 0.50 | 0.26 | 0.26 | 0.38 | 0.55 | 0.35 | 0.3 |
| STD(N) | 0.80 | 0.79 | 0.79 | 0.78 | 0.81 | 1.31 | 0.79 | 0.78 | 0.85 | 1.15 | 0.81 | 0.7 |
| STD(AP) | 0.50 | 0.49 | 0.48 | 0.47 | 0.51 | 1.27 | 0.48 | 0.47 | 0.57 | 1.17 | 0.52 | 0.5 |
| STD(I) | 4.20 | 4.19 | 4.18 | 4.18 | 4.11 | 7.08 | 4.08 | 4.08 | 4.38 | 7.09 | 4.24 | 4.1 |
| STD(X) | 1.04 | 1.03 | 1.03 | 1.04 | 1.03 | 2.24 | 1.02 | 1.02 | 1.08 | 2.07 | 1.06 | 1.0 |
| STD(M) | 1.08 | 1.08 | 1.08 | 1.08 | 1.06 | 1.74 | 1.06 | 1.06 | 1.12 | 1.63 | 1.10 | 1.0 |
| STD(NX) | 0.35 | 0.35 | 0.35 | 0.35 | 0.33 | 0.83 | 0.32 | 0.32 | 0.38 | 0.77 | 0.36 | 0.3 |
| STD(TT) | 0.32 | 0.32 | 0.31 | 0.30 | 0.29 | 0.66 | 0.27 | 0.26 | 0.28 | 0.58 | 0.26 | 0.2 |
| CORR(C,Y) | 0.31 | 0.32 | 0.33 | 0.32 | 0.33 | -0.11 | 0.34 | 0.33 | 0.32 | 0.13 | 0.39 | 0.4 |
| CORR(N,Y) | 0.87 | 0.87 | 0.88 | 0.89 | 0.86 | 0.41 | 0.88 | 0.89 | 0.83 | 0.41 | 0.86 | 0.8 |
| CORR(AP,Y) | 0.61 | 0.62 | 0.64 | 0.65 | 0.60 | 0.36 | 0.64 | 0.65 | 0.53 | 0.44 | 0.60 | 0.6 |
| CORR(I,Y) | 0.94 | 0.94 | 0.94 | 0.94 | 0.93 | 0.76 | 0.94 | 0.94 | 0.91 | 0.73 | 0.92 | 0.9 |
| CORR(X,Y) | 0.09 | 0.10 | 0.11 | 0.12 | 0.20 | -0.35 | 0.23 | 0.24 | 0.03 | -0.29 | 0.10 | 0.1 |
| CORR(M,Y) | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.77 | 0.96 | 0.96 | 0.96 | 0.78 | 0.96 | 0.9 |
| CORR(NX,Y) | -0.59 | -0.59 | -0.58 | -0.58 | -0.54 | -0.56 | -0.53 | -0.53 | -0.61 | -0.53 | -0.58 | -0.5 |
| CORR(TT,Y) | 0.50 | 0.50 | 0.49 | 0.48 | 0.45 | -0.08 | 0.44 | 0.43 | 0.45 | -0.13 | 0.43 | 0.4 |
| CORR(S,Y) | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 | 0.84 | 0.97 | 0.97 | 0.94 | 0.81 | 0.95 | 0.9 |
| CORR(W,Y) | 0.50 | 0.52 | 0.55 | 0.55 | 0.49 | -0.33 | 0.54 | 0.55 | 0.44 | -0.25 | 0.53 | 0.5 |
| CORR(I,S) | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.82 | 0.96 | 0.97 | 0.96 | 0.82 | 0.96 | 0.9 |
| CORR(TT,NX) | -0.39 | -0.39 | -0.40 | -0.41 | -0.38 | 0.73 | -0.40 | -0.41 | -0.38 | 0.73 | -0.39 | -0.4 |
| CORR(N,AP) | 0.15 | 0.17 | 0.21 | 0.24 | 0.13 | -0.69 | 0.21 | 0.24 | -0.03 | -0.62 | 0.11 | 0.1 |
| CORR(N,W) | 0.07 | 0.10 | 0.15 | 0.17 | 0.05 | -0.97 | 0.14 | 0.17 | -0.08 | -0.95 | 0.07 | 0.1 |
| CORR(Y,Y*) | 0.07 | 0.08 | 0.10 | 0.12 | 0.21 | -0.17 | 0.25 | 0.28 | 0.09 | 0.03 | 0.18 | 0.2 |
| CORR(C,C*) | 0.72 | 0.67 | 0.57 | 0.45 | 0.80 | 0.68 | 0.67 | 0.56 | 0.91 | 0.80 | 0.83 | 0.7 |
| CORR(I,I*) | -0.23 | -0.22 | -0.20 | -0.18 | -0.13 | -0.69 | -0.10 | -0.07 | -0.28 | -0.67 | -0.24 | -0.2 |
| CORR(NX,NX*) | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.0 |
| CORR(X,X*) | -0.09 | -0.08 | -0.06 | -0.05 | 0.02 | -0.87 | 0.05 | 0.07 | -0.16 | -0.83 | -0.10 | -0.0 |
| CORR(M,M*) | -0.23 | -0.22 | -0.21 | -0.20 | -0.12 | -0.80 | -0.09 | -0.07 | -0.28 | -0.76 | -0.21 | -0.1 |
| CORR(AP,AP*) | 0.02 | 0.01 | 0.00 | -0.01 | 0.26 | 0.22 | 0.23 | 0.22 | 0.39 | 0.27 | 0.36 | 0.3 |
| CORR(N,N*) | 0.28 | 0.27 | 0.28 | 0.28 | 0.32 | -0.15 | 0.33 | 0.33 | 0.27 | -0.32 | 0.26 | 0.2 |
| CORR(W,W*) | 0.25 | 0.25 | 0.27 | 0.28 | 0.35 | -0.36 | 0.37 | 0.39 | 0.32 | -0.33 | 0.38 | 0.4 |

Note: STD stands for standard deviation, AR1 for the AR1 coefficient and CORR for the correlation coefficient. The numbers 0, 0.2, 0.6 and 1 refer to the value of $\phi_g$ in each case.

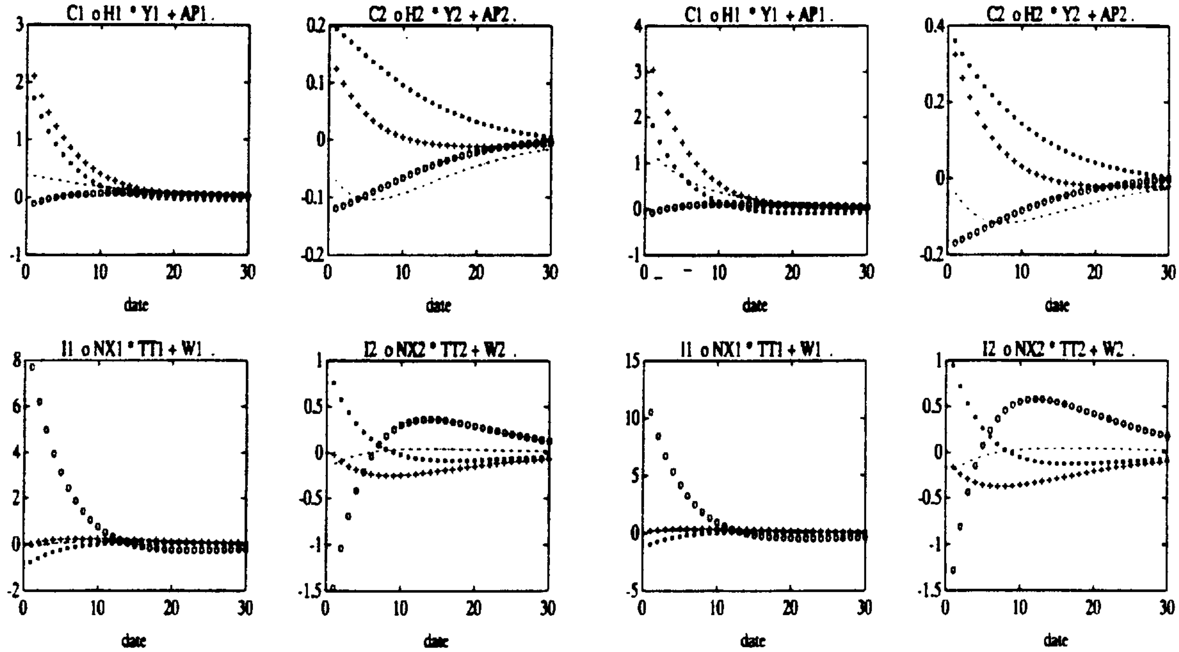


Figure 2.2: Left panel: Standard Model with Perfect competition (T1). Right Panel: Standard Model with Imperfect Competition (T2)

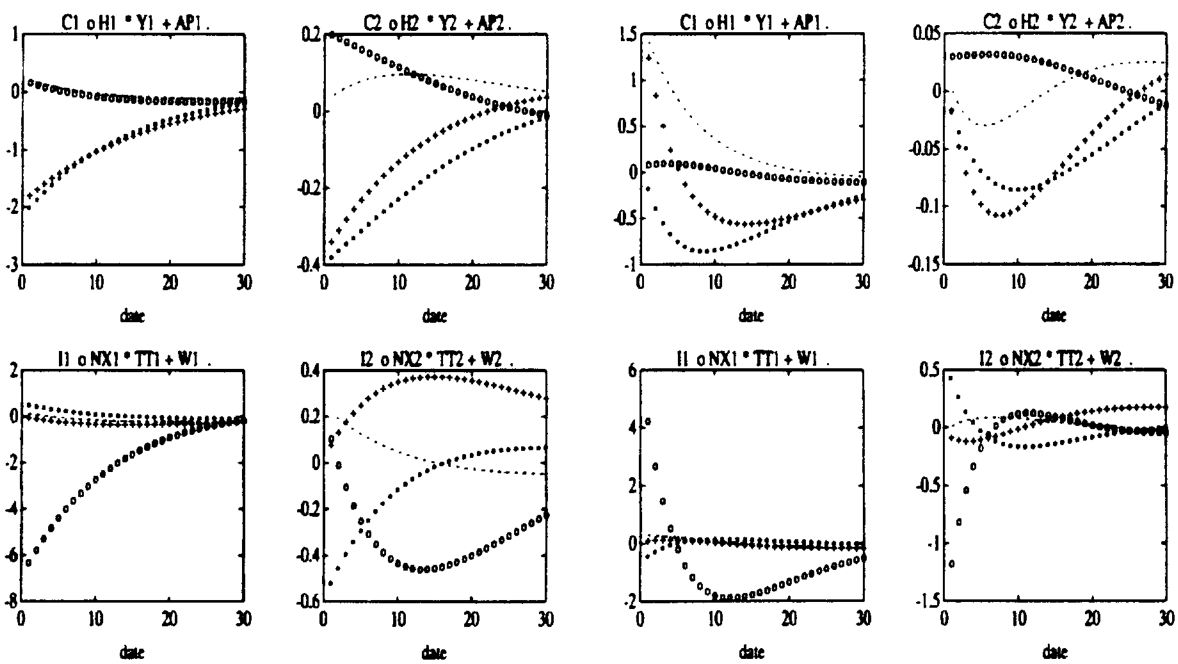


Figure 2.3: Left panel: Model with only Markup shocks (M1). Right Panel: Model with variable Markups (TM1)

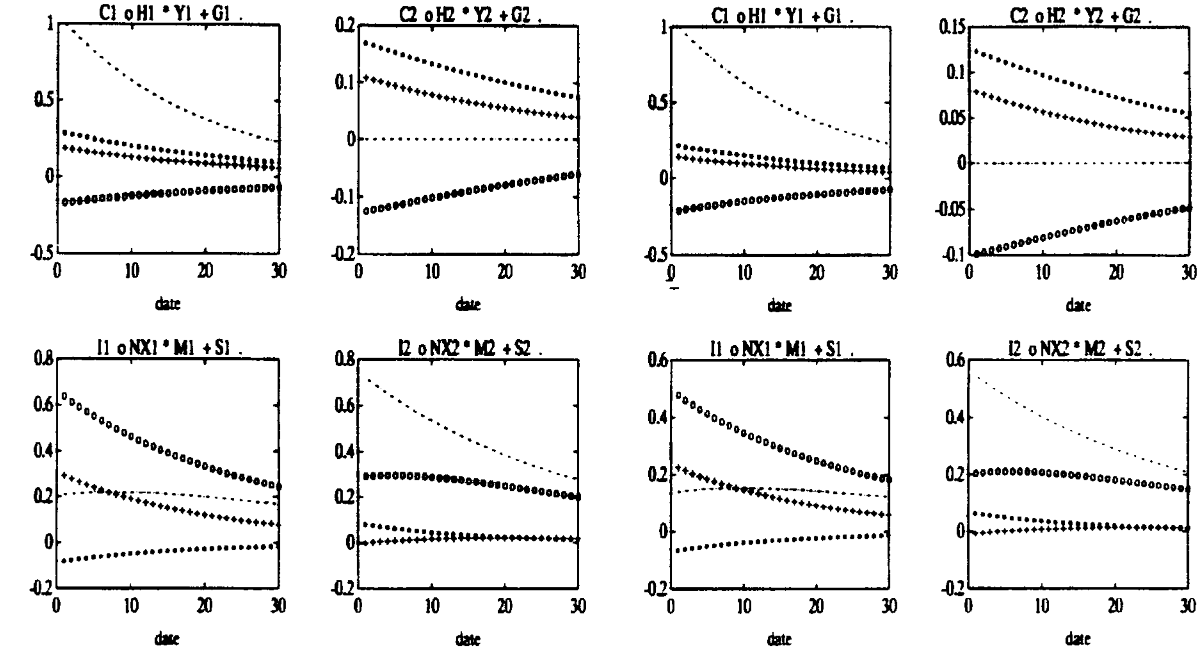


Figure 2.4: Left panel: Government Shock ($\phi_g$ = 0)(G1). Right Panel: Government Shock ($\phi_g$ = 0.2)(G2)

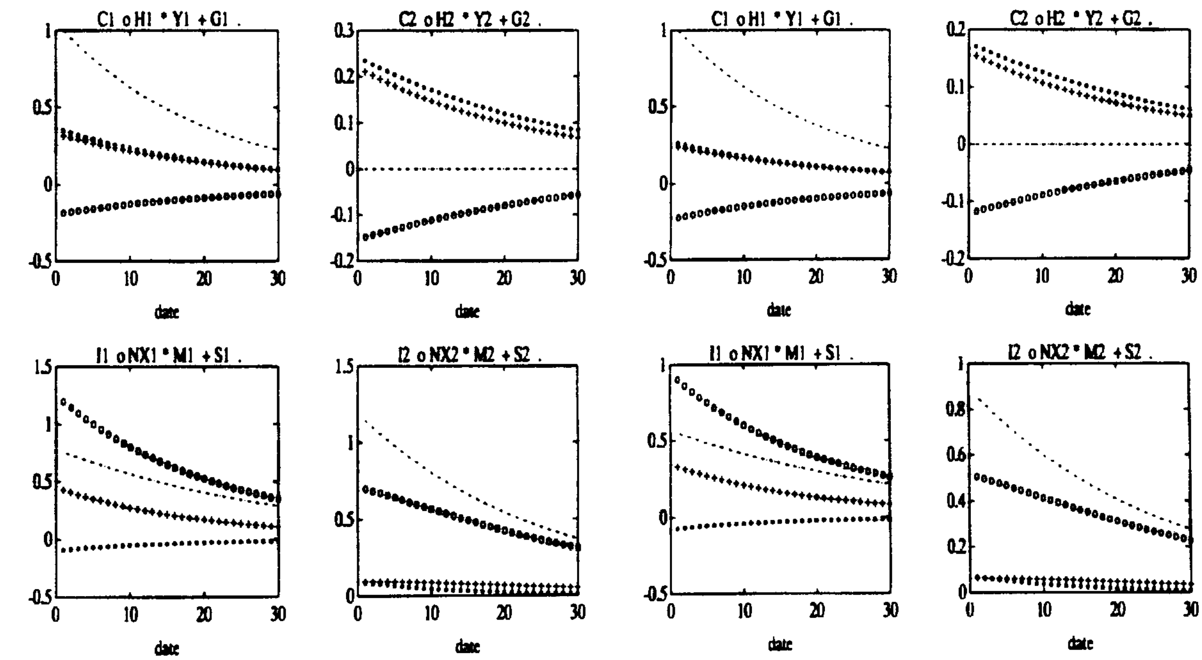


Figure 2.5: Left panel: Government Shock with Imperfect Competition ($\phi_g$ = 0) (G1). Right Panel: Government Shock with Imperfect Competition ($\phi_g$ = 0.2) (G2)

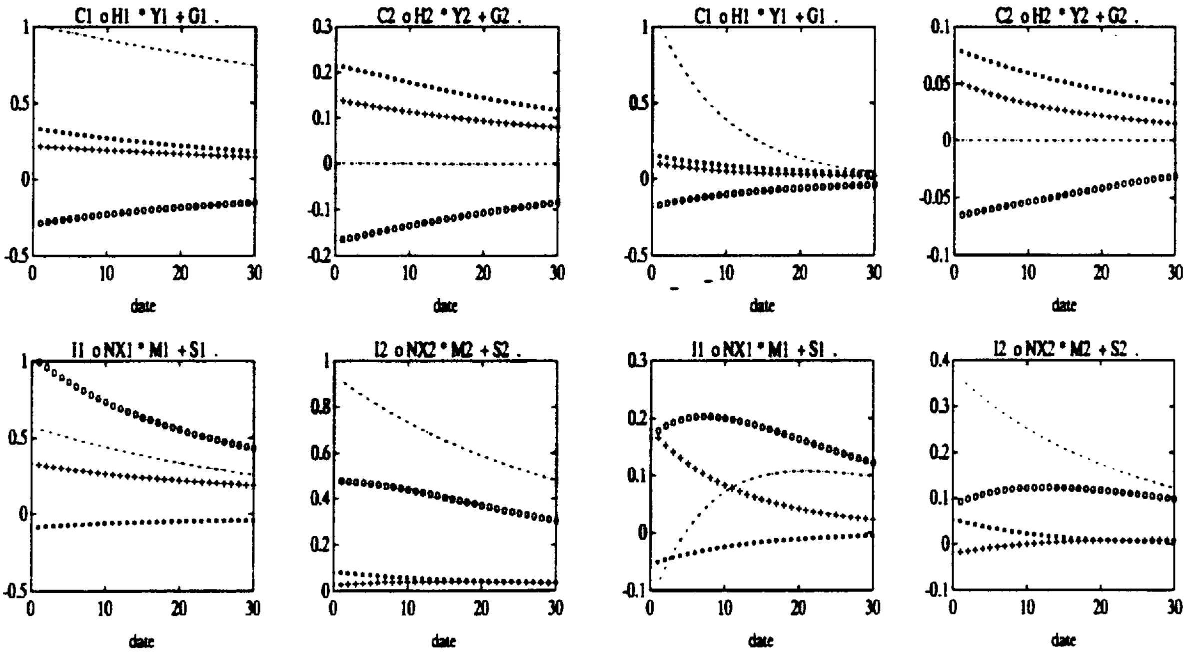


Figure 2.6: Left panel: Permanent Government Shock ($\phi_g = 0$) (G1). Right Panel: Temporary Government Shock ($\phi_g = 0.2$) (G2)

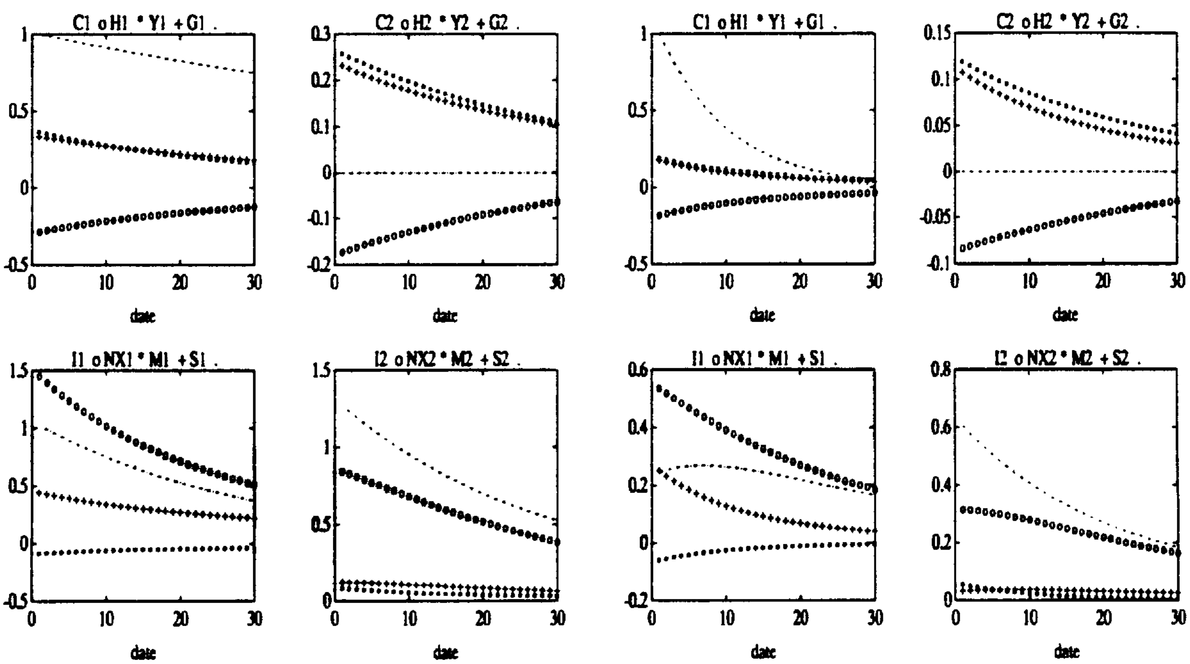


Figure 2.7: Left panel: Permanent Government Shock with Imperfect Competition ($\phi_g = 0$) (G1). Right Panel: Temporary Government Shock with Imperfect Competition ($\phi_g = 0.2$) (G2)

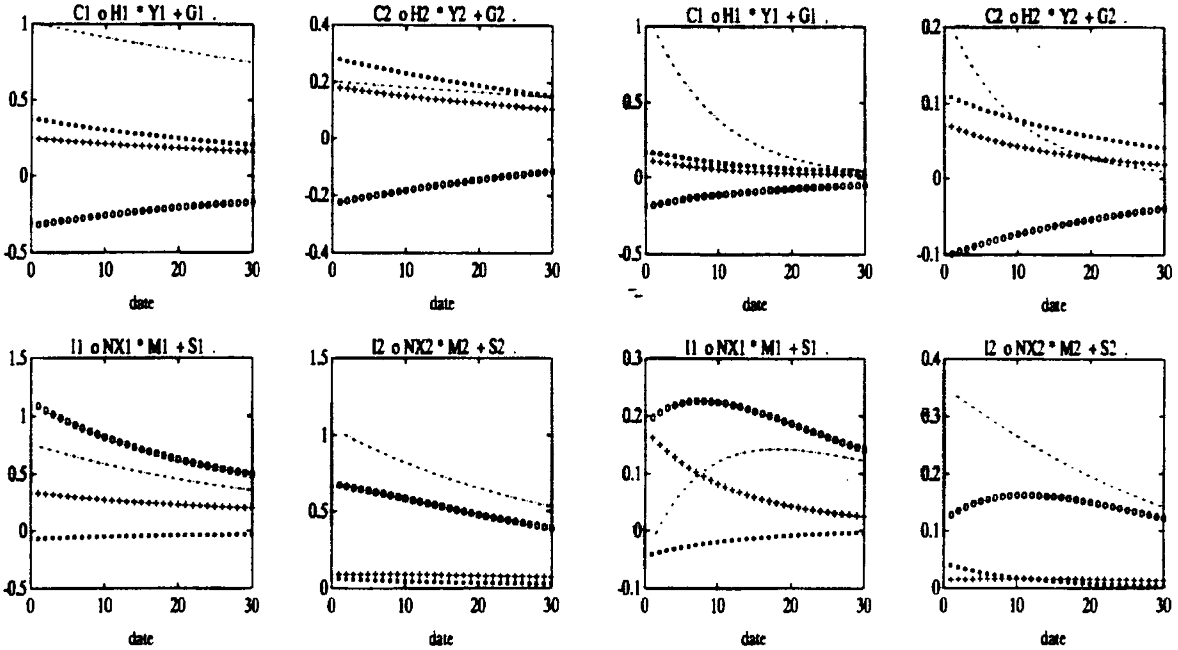


Figure 2.8: Left panel: Permanent Government Shock (Corr(G,G*) = 0.2) (G1). Right Panel: Temporary Government Shock (Corr(G,G*) = 0.2) (G2)

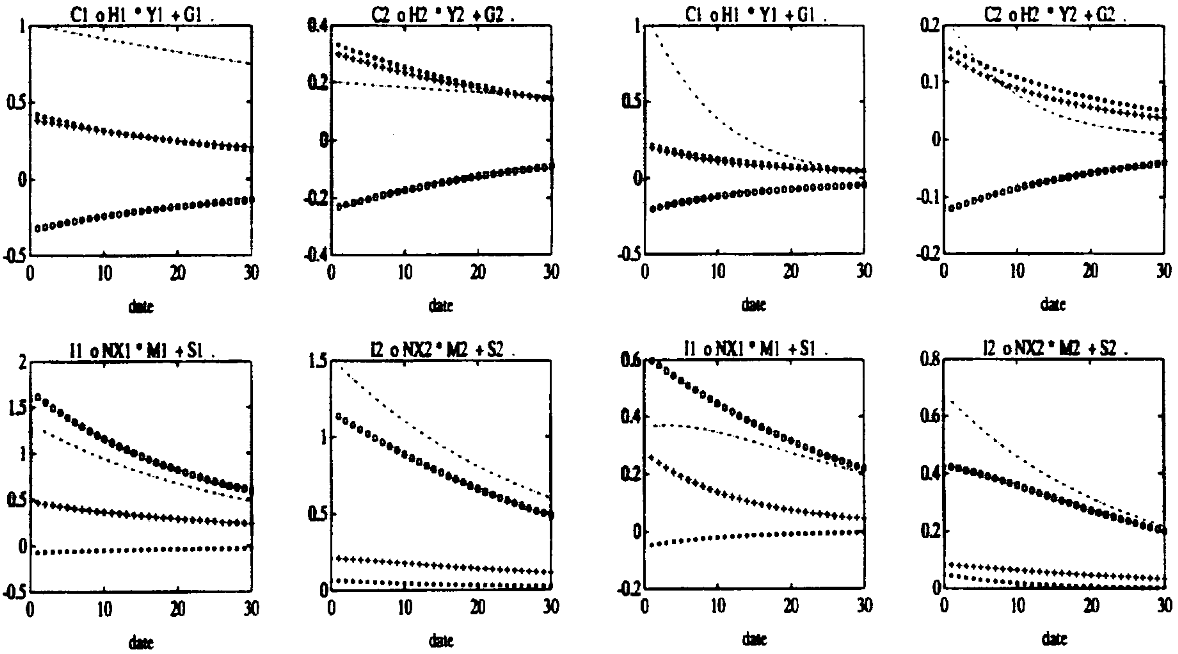


Figure 2.9: Left panel: Permanent Government Shock with Imperfect Competition (Corr(G,G*) = 0.2) (G1). Right Panel: Temporary Government Shock with Imperfect Competition (Corr(G,G*) = 0.2) (G2)

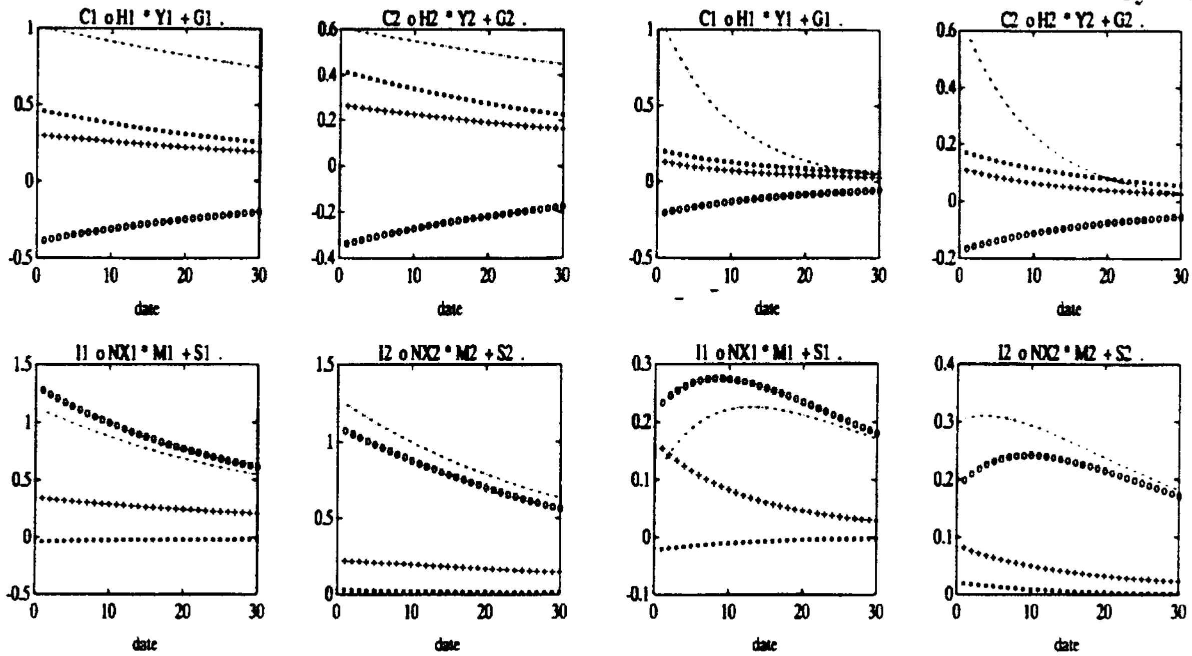


Figure 2.10: Left panel: Permanent Government Shock (Corr(G,G*) = 0.6) (G1). Right Panel: Temporary Government Shock (Corr(G,G*) = 0.6) (G2)

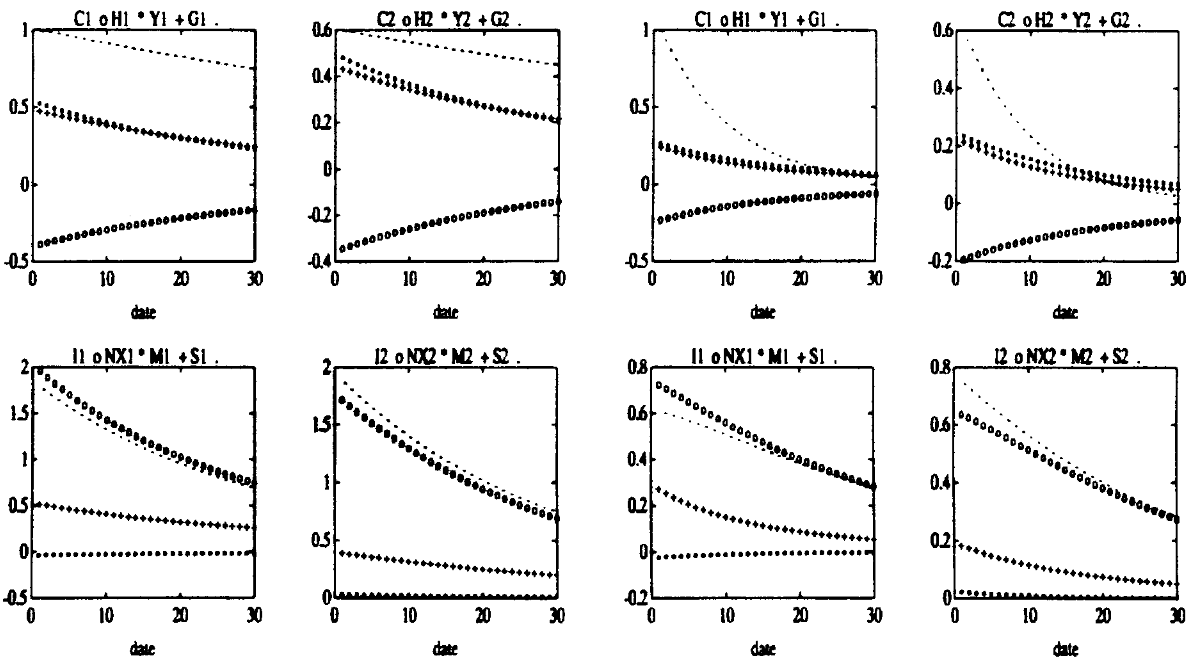


Figure 2.11: Left panel: Permanent Government Shock with Imperfect Competition (Corr(G,G*) = 0.6) (G1). Right Panel: Temporary Government Shock with Imperfect Competition (Corr(G,G*) = 0.6) (G2)

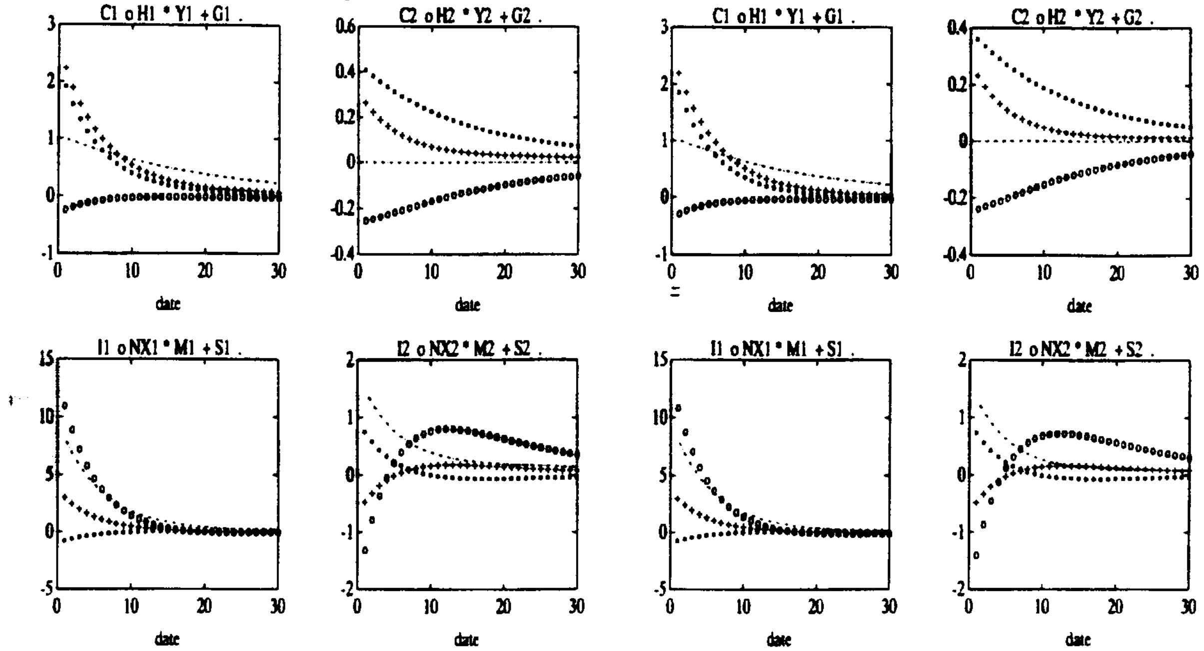


Figure 2.12: Left panel: Technology and Government Shock ($\phi_g = 0$) (TG1). Right Panel: Technology and Government Shock ($\phi_g = 0.2$) (TG1)

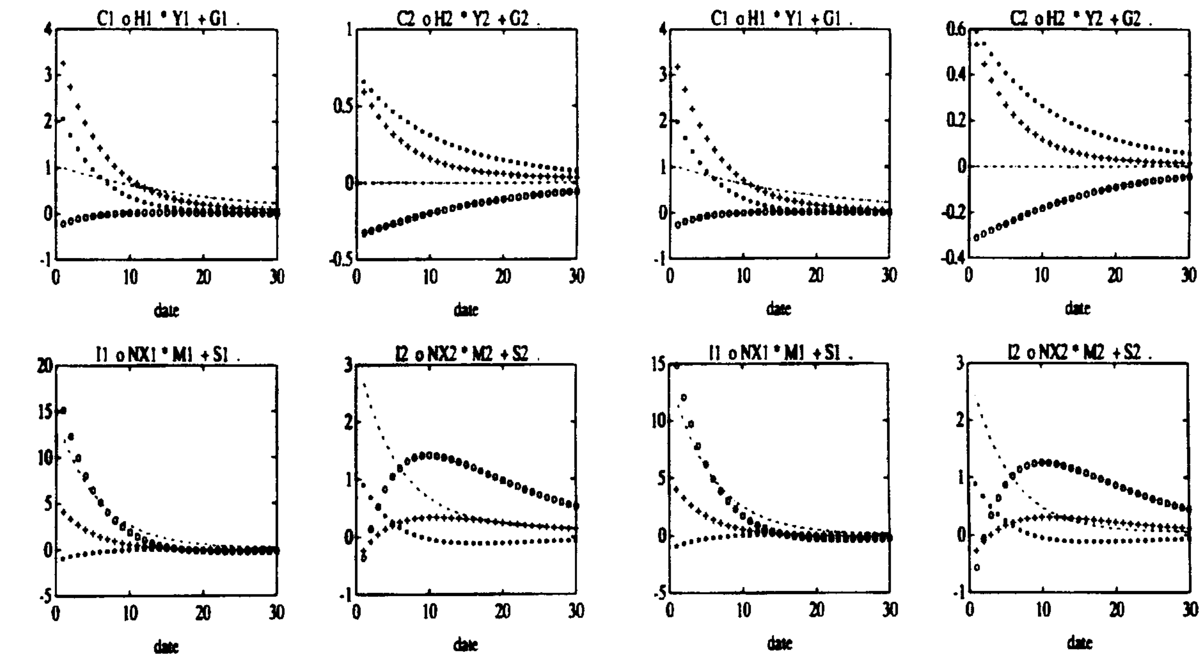


Figure 2.13: Left panel: Technology and Government Shock with Imperfect Competition($\phi_g = 0$) (TG2). Right Panel: Technology and Government Shock with Imperfect Competition ($\phi_g = 0.2$)(TG2)

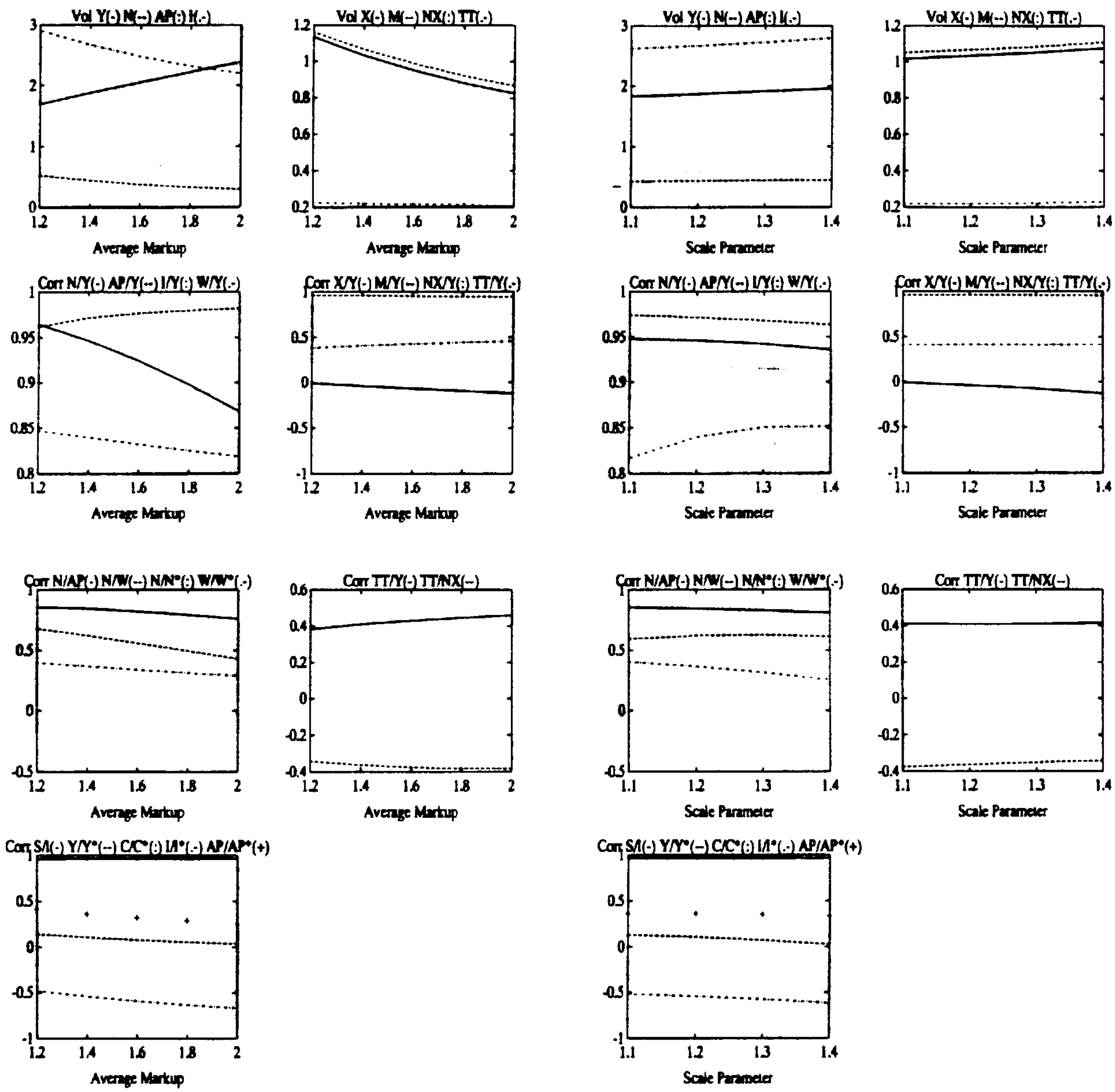

Figure 2.14: Sensitivity analysis Model T2. Imperfect Competition parameters. Average Markup (left panel) and Scale Parameter (right panel). A * denotes foreign variables.

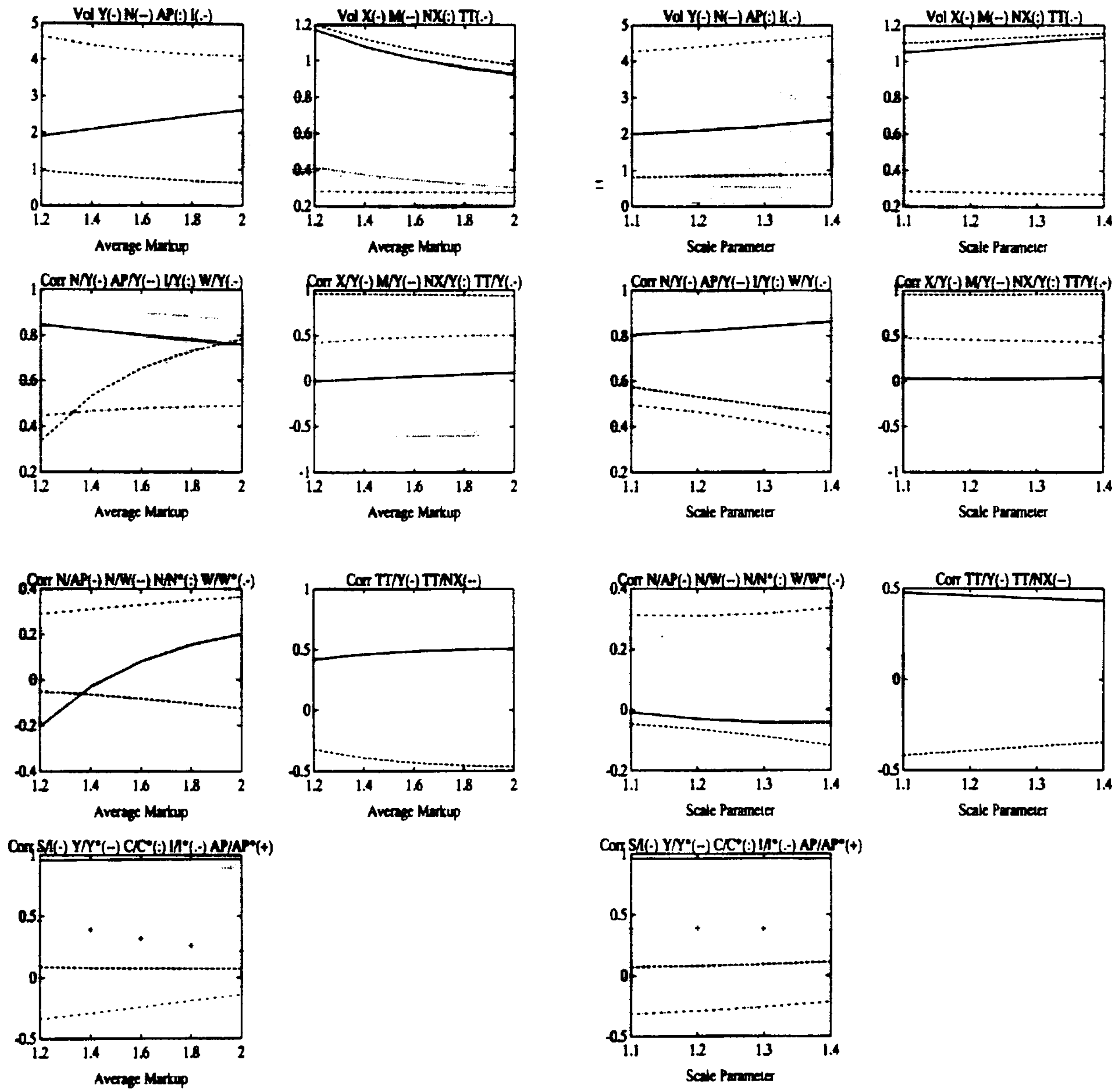


Figure 2.15: Sensitivity analysis Model TM1. Imperfect Competition parameters. Average Markup (left panel) and Scale Parameter (right panel). A * denotes foreign variables.

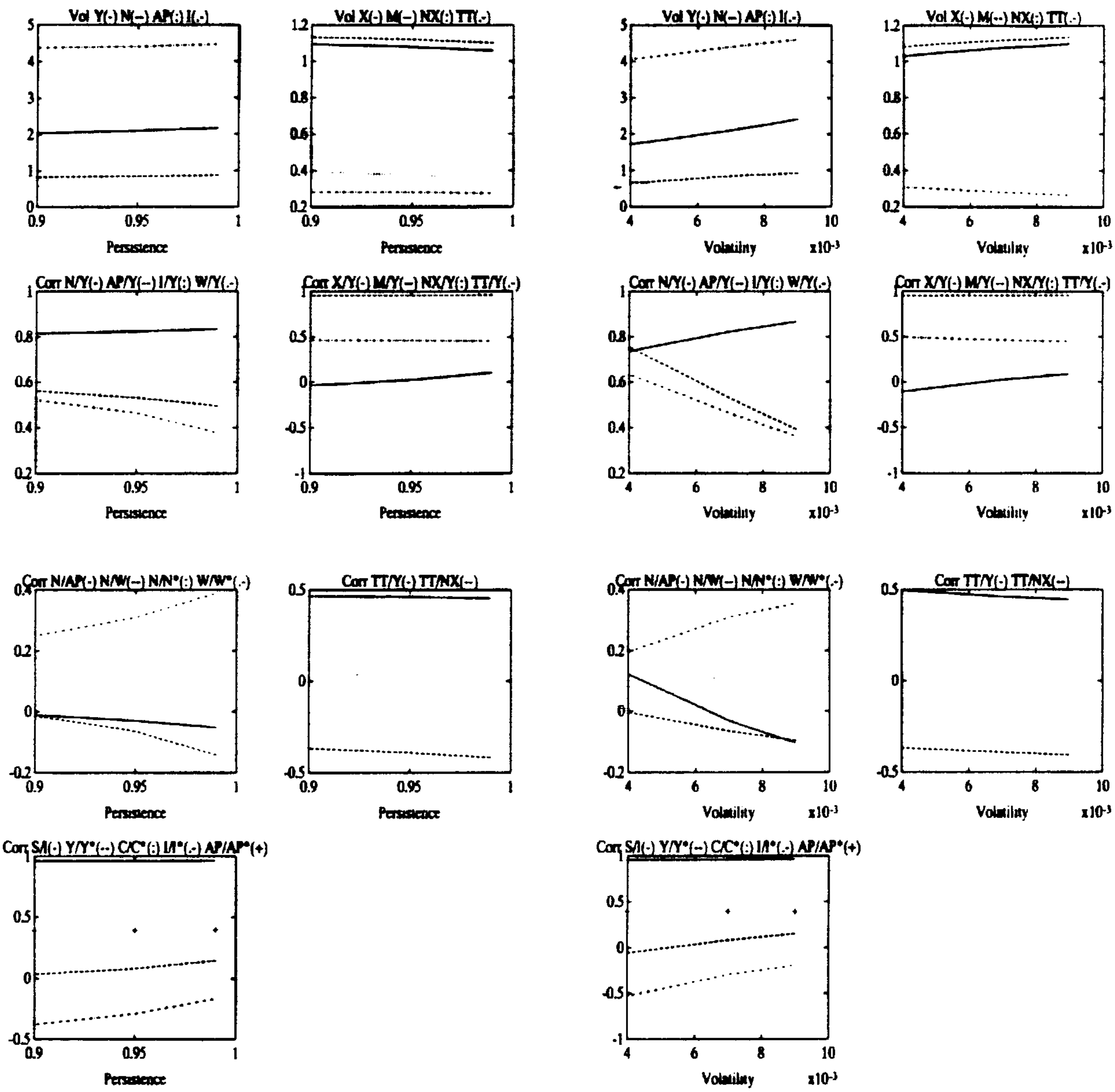


Figure 2.16: Sensitivity analysis Model TM1. Imperfect Competition parameters. Persistence (left panel) and Volatility (right panel) of the markup process. A * denotes foreign variables.

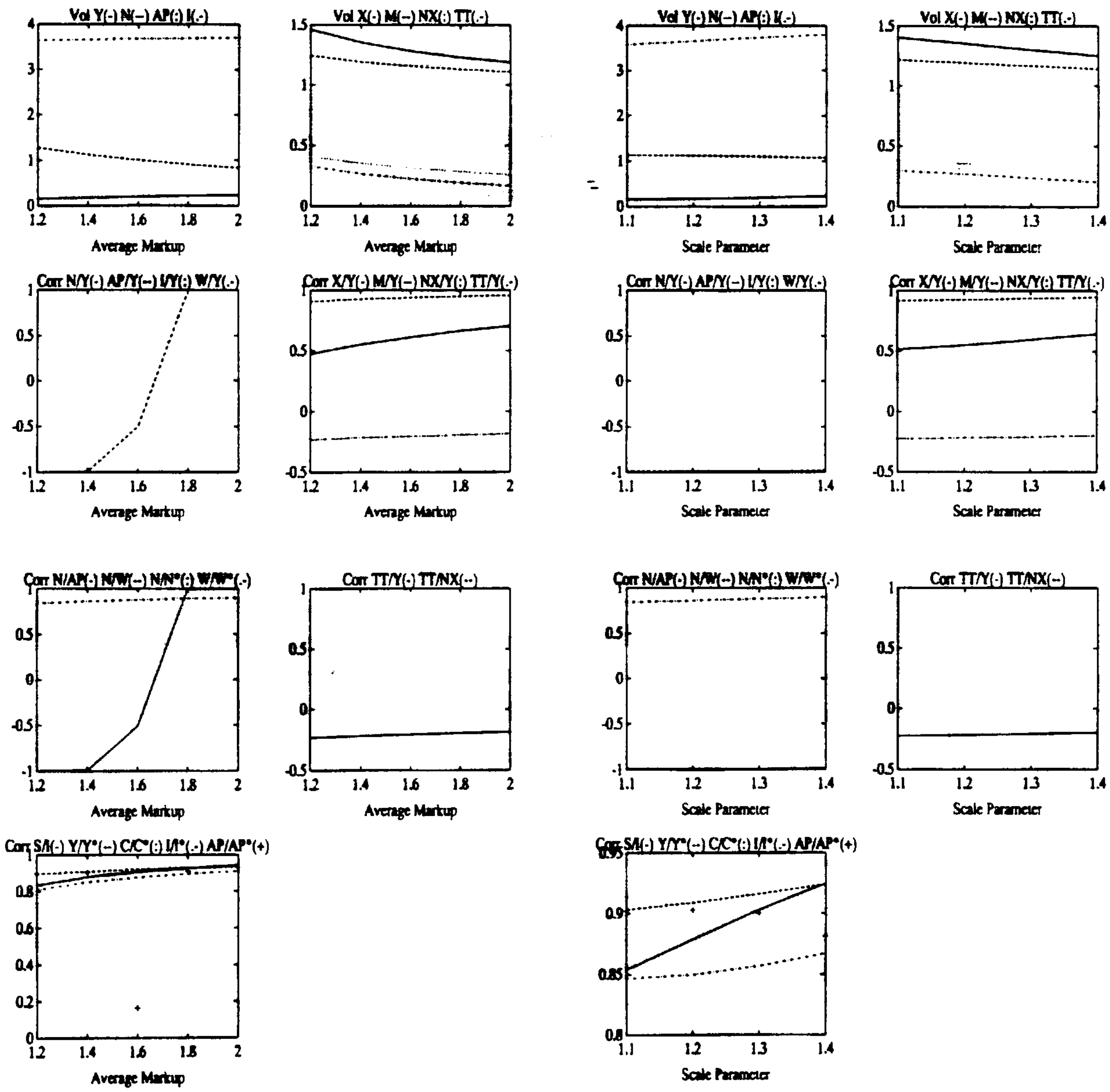


Figure 2.17: Sensitivity analysis Model G1. Imperfect Competition parameters. Average Markup (left panel) and Scale Parameter (right panel). A * denotes foreign variables.

# Chapter 3

# Household Production*

## 3.1 Introduction

A central objective of the RBC research program is to construct models consistent with observed fluctuations in aggregate economic variables. We have seen in the previous chapters that neither the standard RBC model nor the standard model augumented by imperfect competition and indivisible labor can account for the main features of international business cycles, and in particular for the pattern of international comovements.

Therefore, in this Chapter we move one step forward and examinine the properties of an international business cycle model with household production. There are several reasons why this may be an interesting undertaking. Theoretically, household production can provide a firm rationale for the presence of nontraded goods in an international business cycle model and highlight a channel through which the substitution effects typical of labor markets over the business cycle may be accounted for (e.g. entering the work force vs. working at home). Moreover, Stockman and Tesar (1994) have found that taste shocks can help to rationalize international comovements of prices. Household production shocks may be used to justify the presence of otherwise unexplainable taste shocks in the utility function of the representative agent of a country.

Household production also appears to be an important feature of the real world. Formal and informal measures of the importance of the household sector have suggested that this sector's output represents between 20 and 50 percent of the value of measured gross national product in several OECD countries (Eisner (1988)). In addition, the Michigan Time Use survey, as quoted by Hill (1984) or Juster and Stafford (1991), reports that a typical married couple spend 25 percent of their time working unpaid at home while paid work amounts to about 33 percent of their time. These figures suggest that the inclusion of household production in a business cycle model may have important implications for our understanding of cyclical dynamics at an international level and account for some of the unexplained aspects of the data.

*This Chapter is a revised version of Canova and Ubide (1995).

Recently Benhabib, Rogerson and Wright (BRW henceforth) (1991), Greenwood and Hercowitz (1991) and Greenwood, Rogerson and Wright (GRW) (1993) have examined the properties of closed economy RBC models with household production and have shown that these models outperform existing RBC models in matching several features of the data, including the volatility of market output, the relative volatility of consumption and investment to either market output or productivity and the correlation between market hours and productivity. Fisher (1992) and McGrattan, Rogerson and Wright (1992) (MRW) have estimated closed economy models with household production, obtaining significant estimates of the household production parameters. These authors have also performed fiscal policy exercises and reached very different conclusions relative to standard models. Rios-Rull (1993) has developed an overlapping generations model to study the cross-sectional wage, education and employment profile of workers in the US. He finds that lower-wage, less skilled or older individuals tend to devote more time to working at home than in the market.

To the best of our knowledge, no one has yet considered the effects of household production in an open economy framework. Our work attempts to fill this gap by asking two basic questions. First, can a model solely driven by disturbances to the household technology account for the business cycle features of international data? Second, is it possible to improve the performance of existing RBC models by considering shocks to both market and household technologies? Specifically, can we obtain reasonably high saving/investment correlations and generate positive comovements in labor input, investment, imports and exports across countries without simultaneously producing unreasonably high cross country consumption correlations?

Thus, we present in Section 3.2 another extension of the two country general equilibrium model of BKK (1993) where each country produces one imperfectly substitutable tradable good with a market technology and one nontradable good with a household technology. Both technologies are subject to stochastic productivity disturbances and require capital and labour. Since the household produced good can only be consumed, household production disturbances play the role of 'taste' shocks. These shocks change the composition of the bundle consumed by the agents in equilibrium, the allocation of time between market and nonmarket activities and the composition of investment by sector therefore producing dynamics which are different from those generated by disturbances to the market technology. In addition, because household production is not part of measured GNP, disturbances to the household technology affect market output only to the extent that market and nonmarket goods are complements and the degree of substitution between the types of goods will be crucial for determining the features of domestic and international transmission. This feature critically distinguishes our model from those of Stockman and Tesar (1994) or Ravn (1993) and will help us account for some of the most puzzling features of the actual data.

Our model is rich enough to allow for several types of mechanisms transmitting cycles across countries. First, international cycles will emerge because shocks are correlated across countries. Second, shocks to the market technology will produce international repercussions because of imports and exports of capital. Finally, shocks to the household technology create international cycles because of consumption interdependencies across countries.

In Section 3.3 we describe in detail the calibration of the model. In Section 3.4 we present a quantitative analysis of three symmetric versions of the model: one where only disturbances to the market technology are present, which will serve as a benchmark for comparison; a second one where only disturbances to the household technology exist and third one where both types of shocks are present. We show that when only household production disturbances are present the model seems to be able to reproduce the main regularities of international business cycles. We also demonstrate that when both types of disturbances are present the model is able to account for several previously unexplained features of the data, including the low cross country correlation of consumption and the positive cross country correlation of output and investment. Overall, the addition of household production significantly improves the fit of a standard international RBC model. In Section 3.5 we introduce cross country asymmetries in the process for the disturbances and we study whether this modification influences the properties of the model. In this Section we also perform sensitivity analysis to check whether the outcomes of the model depend on the choice of unmeasured parameters or of parameters for which a wide range of empirical estimates exist. We find that the basic features of the simulations do not change when asymmetries are introduced and that results are largely insensitive to the choice of parameters within a reasonable range. The only parameters which are important in determining the qualitative features of the simulations are those describing the elasticity of substitution between imports and exports and the share of imports. Section 3.6 concludes.

## 3.2 The Model Economy

The theoretical framework we use extends again the one of BKK (1993) to include household produced goods. It is a two country model where each country specializes in the production of one tradable (market) good and one household (nonmarket) good. Countries are populated by one representative agent maximizing her utility and living forever and there are no restrictions to move capital or exchange market goods across borders, but household goods and labor can not be traded across countries. We also assume that agents can write international contingent claims which promise to pay a fraction of the market good while contingent claims promising to pay the non market good are written and traded only domestically.

Preferences of the representative agent of country $h = 1,2$ are given by

$$W_h = E_0 \sum_{t=0}^{\infty} \beta^t U_h(CM_{ht}, CN_{ht}, L_{ht}) \tag{3.1}$$

where $W$ is total discounted lifetime utility, $U_h(.)$ is the instantaneous utility function in country $h$, E is the conditional expectations operator, $\beta$ is the subjective discount factor, $CM_{ht}$ is consumption of the market good, $CN_{ht}$ is consumption of the household good and $L_{ht}$ is leisure. The instantaneous utility is of the form:

$$U_h = \frac{(C_{ht}^b L_{ht}^{1-b})^{1-\tau} - 1}{1 - \tau} \tag{3.2}$$

where $C_{ht} = [aCM_{ht}^e + (1-a)CN_{ht}^e]^{1/e}$ is a CES aggregator, $0 \leq a \leq 1$ is the relative weight of market goods to household goods and $\frac{1}{1-e}$ is the elasticity of substitution between market and household goods, $0 \leq b \leq 1$ is the relative weight of consumption to leisure, $\tau$ the risk aversion parameter and is selected in order to produce constant market hours along a balanced growth path. To economize on parameters and because of the results of Hansen (1989) we set $\tau$=1 and consider the logarithmic version of (3.2):

$$U_h = \frac{b}{e}\ln[aCM_{ht}^e + (1-a)CN_{ht}^e] + (1-b)\ln(L_{ht}) \tag{3.3}$$

Total endowment of time is normalized to one and leisure choices are constrained by

$$1 \geq HN_{ht} + HM_{ht} + L_{ht} \geq 0 \tag{3.4}$$

where $HM_{ht}$ are hours worked in the market sector and $HN_{ht}$ are hours worked in the household sector at time $t$ in country $h$.

Each country $h$ produces an intermediate good $Y_h$ and a household good $CN_h$ with a Cobb-Douglas technology

$$Y_{ht} = f(HM_{ht}, KM_{ht}) = AM_{ht}KM_{ht}^{\theta}(X_{ht}HM_{ht})^{1-\theta} \tag{3.5}$$

$$CN_{ht} = g(HN_{ht}, KN_{ht}) = AN_{ht}KN_{ht}^{\eta}(X_{ht}HN_{ht})^{1-\eta} \tag{3.6}$$

where $AM_{ht}$ ($AN_{ht}$) is a stationary disturbance to the market (household) sector, $KM_{ht}$ ($KN_{ht}$) is the stock of capital used in the production of the market (household) good, $X_{ht}$ is a labour augmenting Hicks-neutral technological progress, assumed to grow at a common rate $\gamma$-1 across sectors and countries and $\theta$ and $\eta$ are share parameters

Recalling Chapter 1, we open the economy by assuming that $Y_{ht}$ can be either used domestically or exported

$$Y_{1t} = A_{1t} + \frac{\Pi_2}{\Pi_1}\tilde{A}_{2t} \tag{3.7}$$

$$Y_{2t} = B_{1t} + \frac{\Pi_1}{\Pi_2}\tilde{B}_{2t} \tag{3.8}$$

where $\tilde{A}_{2t}$ and $B_{1t}$ are exports and imports of country 1 and $\Pi_h$ is the welfare weight associated with country $h$, $\Pi_1 + \Pi_2 = 1$. We let $A_{2t}=\frac{\Pi_2}{\Pi_1}\tilde{A}_{2t}$ and $B_{2t}=\frac{\Pi_1}{\Pi_2}\tilde{B}_{2t}$. Imports and domestic market goods are then used in the production of a final domestic market good in each country, $V_{ht}$, according to a CES technology of the form (see Armington (1969)):

$$V_{1t} = (\varpi_1 A_{1t}^{1-\rho} + \varpi_2 B_{1t}^{1-\rho})^{\frac{1}{1-\rho}} \tag{3.9}$$

$$V_{2t} = (\varpi_1 B_{2t}^{1-\rho} + \varpi_2 A_{2t}^{1-\rho})^{\frac{1}{1-\rho}} \tag{3.10}$$

where $1/\rho$ is the elasticity of substitution between domestic and foreign goods and $\varpi_1$ and $\varpi_2$ are parameters regulating the domestic and foreign content of GNP. The relative price of imports to exports (terms of trade) is then given by:

$$P_{1t} = \frac{\partial V_1/\partial B_{1t}}{\partial V_1/\partial A_{1t}} = \frac{\varpi_2 B_{1t}^{-\rho}}{\varpi_1 A_{1t}^{-\rho}} \tag{3.11}$$

where $\varpi_1 = (1 - MS)^\rho$, $\varpi_2 = MS^\rho$ and where $MS$ is the import share in output.

Only the market sector produces investment goods but the national stock of capital is used in both the market and household sectors. The law of motion of capital is:

$$K_{ht+1} = (1-\delta)K_{ht} + I_{ht} \tag{3.12}$$

where $K_{ht}=KM_{ht}+KN_{ht}$ is the total stock of capital of country $h$, $0< \delta <1$ is the depreciation rate, common to both sectors and countries and $I_{ht}$ is total investment in country $h$. Contrary to standard one good models we do not need to include adjustment costs in (3.12) because the presence of two tradable goods prevents the model from generating excessively large capital flows in response to technology disturbances.

The aggregate resources constraint for the traded goods in the world economy is

$$\Pi_1 V_{1t} + \Pi_2 V_{2t} = \Pi_1(CM_{1t} + I_{1t}) + \Pi_2(CM_{2t} + I_{2t}) \tag{3.13}$$

Note that when the two countries are equally wealthy in per capita terms, the welfare weights measure the number of agents in each country. Therefore, we can meaningfully discuss country size in the model by varying these weights between 0 and 1.

Production disturbances are assumed to follow a first order Markov process

$$A_{t+1} = CA_t + \epsilon_{t+1} \tag{3.14}$$

where $A_{t+1} = [AN_{1t}, AN_{2t}, AM_{1t}, AM_{2t}]'$

$$C = \begin{pmatrix} C_{n1n1} & C_{n1n2} & C_{n1m1} & C_{n1m2} \\ C_{n2n1} & C_{n2n2} & C_{n2m1} & C_{n2m2} \\ C_{m1n1} & C_{m1n2} & C_{m1m1} & C_{m1m2} \\ C_{m2n1} & C_{m2n2} & C_{m2m1} & C_{m2m2} \end{pmatrix} \tag{3.15}$$

$$\epsilon_{t+1} \sim N\left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} V_{n1n1} & V_{n1n2} & V_{n1m1} & V_{n1m2} \\ V_{n2n1} & V_{n2n2} & V_{n2m1} & V_{n2m2} \\ V_{m1n1} & V_{m1n2} & V_{m1m1} & V_{m1m2} \\ V_{m2n1} & V_{m2n2} & V_{m2m1} & V_{m2m2} \end{pmatrix}\right) \tag{3.16}$$

This general specification for the disturbances encompasses several special cases of interest:

1. If $C_{m1m1} \neq C_{m2m2}$ and/or $C_{n1n1} \neq C_{n2n2}$, the persistence of shocks is different across countries. This may be the result of different sizes, different industrial or trade structures or different degrees of openness.

2. If $C_{m1m1} \neq C_{n1n1}$ and/or $C_{m2m2} \neq C_{n2n2}$, the persistence of the household shocks is different from the persistence of the market shocks. This can be thought to roughly represent different degrees of openness in the two sectors.

3. If $C_{m1m2} \neq C_{m2m1}$ and/or $C_{n1n2} \neq C_{n2n1}$, there are asymmetries in international spillovers that may reflect country size, technological development, or the fact that a small or less developed country may benefit more from an innovation in a large or more developed country than vice versa.

4. If $C_{m1n2} \neq C_{m1m2}$ and/or $C_{m2m1} \neq C_{m2n1}$, technological disturbances in a country may affect foreign sectors differently depending on the type of industry a country specializes in, i.e. a country specialized in heavy industry is not likely to impact the household sector of the other country.

5. If $V_{m1m1} \neq V_{m2m2}$ and/or $V_{n1n1} \neq V1_{n2n2}$, the volatilities of the shocks are different across countries reflecting the fact that larger or more open countries enjoy a better diversification of risks because of more complete markets or greater variety of industries.

6. If $V_{m1m2} \neq V_{n1n2}$, the sectoral shocks will have different cross country correlations and this may reflect differences in trade and industry structures or their relative sizes.

It is useful to compare our model specification with others which introduce nontradable goods in international RBC models. Stockman and Tesar (1994) consider a traded and nontraded sector in their model with production functions of the form

$$\begin{aligned} Y_{ht}^{T} &= f(HM_{ht}, KM_{ht}) \\ Y_{ht}^{NT} &= g(HN_{ht}, KN_{ht}) \end{aligned} \tag{3.17}$$

and total output can be allocated to consumption or investment in both sectors, i.e.

$$Y_{ht} = Y_{ht}^{T} + Y_{ht}^{NT} = C_{ht}^{T} + C_{ht}^{T*} + I_{ht}^{T} + C_{ht}^{NT} + I_{ht}^{NT} \tag{3.18}$$

Ravn (1993) introduces government spending in the utility function of the domestic agents: $U_h = U_h(D_h, L_h)$ where $D_h = C_h + \mu G_h$. Here government spending benefits only domestic residents and hence plays the role of a nontraded good. The basic difference with our formulation is that in these other setups the nontraded good is part of the resource constraint so that a shock to the nontraded technology affects GNP directly. Here the nontraded good does not enter the computation of measured GNP and therefore a shock to the nontraded good affects GNP only to the extent that market and nonmarket goods are substitutes.

Because there are no distorting taxes or externalities, competitive allocations can be computed using the social planner problem, and terms of trade can be determined using (3.11). To make the problem stationary we first detrend all variables but hours worked and leisure dividing them by the Hicks-neutral technological progress $X_{ht}$. The stationary system is then solved for the steady state and the dynamics in response to the shocks are approximated by log-linearizing the first-order conditions around the steady state as in King, Plosser and Rebelo (1988). We construct 100 samples of 96 periods (the number of quarters of our data) each time drawing shocks from (3.14)-(3.15) for each model specification. Each sample is Hodrick-Prescott filtered and standard deviations and cross correlations are computed. Finally, statistics are averaged over the 100 samples to reduce the importance of sampling variability in the comparisons.

## 3.3 The Calibration of the Model

In calibrating the parameters of the model we follow the existing practice of choosing share parameters to replicate long run averages of the data and utility parameters to match estimates obtained in previous empirical studies. The values that we have selected for $\beta = 0.98$, $\delta = 0.025\%$, $\Pi_1=\Pi_2=0.5$ are standard and do not require discussion. $\theta$ is set to 0.36 which is, approximately, the mean value of the share of capital in production for developed countries (see Zimmermann (1994)). In order to match the CN/Y steady state ratio (0.20-0.50 according to Eisner (1988)), we set $\eta$, the share of capital in the household production function, equal to 0.08 and that gives a steady state CN/Y ratio of 0.2631. GRW (1993), analyzing a closed economy model with household production and government expenditure, selected $\theta = 0.29$ and $\eta = 0.32$ when matching the ratio of consumer durables plus residential structures to output instead of CN/Y. Because the difference between the two values of $\eta$ is significant, we will examine the sensitivity of the results to variations in this parameter.

The choice of $e$, the parameter describing the elasticity of substitution between household and market goods in the utility function, is more problematic since empirical evidence is controversial. Note that the lower is $e$, the smaller is the contribution of household production sector to fluctuations in the economy. Eichenbaum and Hansen (1990) differentiate services from market (nondurable) goods and from consumer durables (which they identify with household production) and find that, regardless of the assumptions made, the two groups of goods are very close substitutes, which would suggest setting $e = 1$. Tesar (1993) and Stockman and Tesar (1994) use data from Kravis and Lipsey (1987) on expenditure shares of consumption of traded and nontraded goods, price indices and per capita income to estimate the elasticity of substitution between traded and nontraded goods and find a value of 0.44, which would suggest again setting $e$ close to 1. MRW (1993) obtain a value of $e$ of 0.385 (with standard error of 0.145) estimating by maximum likelihood a model with household production and a government sector. At a micro level, BRW(1991) use cross-section data from the PSID to estimate an equation relating the relative allocation of time to the long run wage of the form

$$\ln\left(\frac{HM_i}{HN_i}\right) = \alpha_0 + \alpha_1 \ln(w_i) + \epsilon_i. \tag{3.19}$$

They report an estimate of $e$ of about 0.6, a value they believe underestimates the true $e$ because the panel underreports low-wage workers, which are the group with presumably a lower ratio of market to household hours. Finally, Rupert, Rogerson and Wright, using PSID data, estimate $e$ to vary between -0.078 for single males to 0.750 for married couples. Here we use the mean value of existing estimates ($e$=0.8) for our benchmark case (as in BRW (1991)) and experiment with values in the range [0.0,1.0] to examine the sensitivity of the results.

The calibration of foreign trade variables is similar to that of Chapter 2. For the share of imports $MS$ and the elasticity of substitution of Armington aggregator $\rho^{-1}$ we use standard values suggested in the literature. Empirically, $MS$ varies substantially across countries, normally being higher for smaller countries. Ravn (1993) reports values ranging from 38.6% for Switzerland to 7.7% for the U.S.. BKK (1992) use two values (15% and 30%) as a 'normal' and 'large' import share. Here we choose the cross sectional average of the OECD countries 22.5%. (as in Ravn (1993)) for the benchmark case and check the sensitivity of the results to variations of MS in the range [0, 50%]

Values for $\rho^{-1}$ of 1-1.5 have been generally used in general equilibrium models of trade but they are believed to be lower bounds for the actual value since estimates of this elasticity parameter are downward biased because of large measurement errors (see Whalley (1985)). Zimmermann (1994) obtains an expression for this elasticity in his model that depends on tariffs, transportation costs, import shares and terms of trade. The corresponding estimates for OECD countries are in the range [0.6-13.5], averaging 5.4. Because of the variety of values, we use 1.5 as in BKK (1992) for the benchmark case and analyze the sensitivity of the results to changes in this parameter in the range [0,5].

The parameters $a$ and $b$ are chosen to match the long run values of hours worked in the market ($HM^{ss} = 0.33$) and at home ($HN^{ss} = 0.25$). The values we obtain are $a = 0.35$ and $b = 0.63$ which we use in all our experiments.

This set of parameters yields steady state values for CM/Y and for I/Y of 0.70 and 0.29, respectively. These values represent quite well the mean ratios for the OECD countries of our sample (CM/Y=0.61 and I/Y=0.26), once we account for the fact that there is no government sector in the model.

Direct estimation of the parameters of the productivity process, i.e. the matrices C and V, is not possible given the lack of time series data for household production variables. Therefore, we select these parameters to model different scenarios. In the benchmark case the shocks are completely symmetric across countries. The persistence parameter is set to 0.835, which is an average of the estimated persistence of market technological shocks of the major OECD countries, the cross country correlation of the shocks is set to 0.25 and the spillover parameter between the two market technological shocks is set to 0.088 as in BKK (1993). Spillovers between the two household technologies, which could be interpreted as "fashions" transmitted from one country to the other, are set to zero because it is not clear if this transmission would be contemporaneous or with some lags. Cross-sector-cross-country spillovers as well as inter-sector-intra-country spillovers are also set to zero since the sign and the magnitude of these cross effects is unknown.

Finally, we need to select the contemporaneous correlation of the household and market disturbances within a country. This parameter measures the technological incentive to shift economic activity across sectors, since lower values of the correlation generate more frequent sectoral productivity differentials. For the basic experiments we chose a value of 0.66 as in BRW (1991). Such a value is high and limits the contribution of the household sector to the dynamics of the model. In fact, MRW (1993) obtain an estimate of -0.18 for this correlation, which gives greater importance to the household sector in the model. Because of this variety of estimates we perform sensitivity analysis to investigate how alternative settings of this parameter in the range [0,1.0] influence the results.

With this specification of the parameters we study three versions of the model: one where only disturbances to the market technology exist, one where household production shocks are the sole source of disturbance and another where both household and market production shocks displace the economies from their steady state. For each model specification we will consider three subcases (see Appendix): in the first one (named S1) shocks are uncorrelated across countries and there are no spillovers either domestically or internationally. This setup mimics a situation where countries face idiosyncratic disturbances but move together over the business cycle because of trade interdependencies. The second setup (named S2) has correlated shocks and no spillovers. Here we try to mimic a typical situation in OECD countries where nations face somewhat common disturbances but there is very little evidence of lagged transmission of these shocks. In the third setup (named S3) we consider an economy with correlated shocks and spillovers, a scenario which may realistically resemble the economic environment of highly integrated economies like the European Union.

## 3.4 Simulation results

The results of the simulation exercises when the two countries are identical appear in table (3.6) When only household disturbances are considered experiments S2 and S3 are identical (the intercountry spillovers of household disturbances is zero) and we only report one of them.

### 3.4.1 A Model with Disturbances to the Market Technology

In the first panel of table (3.6) we present statistics for a model driven by disturbances to the market technology which serves as a benchmark to compare the improvements obtained with alternative specifications. In this case we set $\epsilon = \eta = 0$ (see GRW (1993)). The first panel of figure 3.1 shows the dynamics of the model following the shock. The model works well along many dimensions but there are at least four aspects of the data which are mismatched regardless of which of the three experiments we consider. First, output, consumption, hours, imports and exports do not fluctuate enough. Second, hours, investment and imports are too highly correlated with output while the correlation between exports and output is too small. Third, consumption is more correlated than output across countries. Fourth, investment, hours, imports and exports are either negatively correlated or show no correlation across countries. In judging the improvements produced by adding household production to the model we will focus primarily on these four aspects of the data.

### 3.4.2 A Model with Disturbances to Household Technology

The results of the experiments when only household production disturbances are present are displayed in the second panel of table (3.6). The second panel of figure 3.1 shows the dynamics of the model induced by these shocks.

As expected, the model generates higher variability in output, consumption and labor variables relative to the benchmark case since agents can substitute both intratemporally as well as intertemporally. The relative variability of consumption is now greater than one, which is true in the data only for U.K.. The relative variability of market hours is very close to one and investment is about three times as volatile as output, as it is in the data. Here investment varies less than in the benchmark case but its composition among sectors changes substantially over the cycle (household investments increase, market investments decrease). The volatility of trade variables is as badly matched as in the benchmark model: exports and imports are at most only as volatile as output while in the data they are about three times as volatile while the volatility of net exports is around 0.7 which is within the range of values found in the data (0.48-1.27).

As in the benchmark case the model generates a very high domestic correlation of hours and consumption with output while the correlation of investment with output drops to 0.4 and the correlation of productivity is quite low relative to the benchmark case. This pattern of correlations is easily accounted for (see impulse responses): a positive shock to the household technology changes the willingness to work in the market for a given wage, shifts the labor supply curve, lowers market consumption, market hours and market output while slightly raising total investment. Such a shock therefore mimics a negative taste shock and induces a "recession" in the market sector. When the shock dies out investment smoothly returns to its steady state and market consumption, market hours and market output move together boosting exports as well.

Qualitatively speaking, imports are more procyclical than exports as in the benchmark model. Quantitatively, exports are more procylical relative to the baseline case. Also, net exports are less negatively correlated with output because consumption, which constitutes the bulk of exports and imports, is less procyclical here than investments are in the basic case. With correlated shocks the procyclicality of exports rises (correlation with output is up to 0.7) and the correlation of net exports with output drops to -0.16. Finally, the saving-investment correlation is very close to one, in agreement with Baxter and Crucini (1993), even when there are no direct cross country spillovers.

All experiments replicate quite well the properties of cross country consumption correlations but fail to display positive comovements of investment and to replicate the high cross country productivity correlations we see in the data. In addition, the cross country labor and output correlations are about 0.8 even without correlated shocks. This pattern of international comovements emerges because, as we have mentioned, a positive shock to the home technology generates a rise in domestic investment and a fall in all market variables. In the foreign country such a disturbance increases market consumption while investment drops substantially. However, in the foreign country all market variables fall as the shock is transmitted from the home country. When the effects of the shock dies out, the recovery will be very similar in both countries. Thus, a positive household production disturbance generates unsyncronized comovements in the consumption of the market good and negative comovements of investment across countries but highly positively correlated comovements in hours and outputs.

It is important to stress that the main channel of reallocation of resources within countries here is between household and market consumption and hours and not between consumption and investment as in the benchmark model. Also, the transmission of shocks across countries is mainly via trade in consumption goods. Canova (1993a) shows that in a model with multiple goods and shocks to either the market technology or government expenditure this channel of propagation of international cycles is minor. Our results suggest that when shocks to the household production drive the cycle, transmission via trade in investment goods may be small.

Concluding, the properties of the model are fairly robust across the three experiments. Contrary to models driven by shocks to the market technology, the current framework can produce the low international consumption correlations and the positive comovement of labor variables across countries we see in the data. However, it still fails to replicate the sign of the comovements of investment and productivity across countries and exaggerates the volatility of both consumption and hours.

### 3.4.3 A Model with Disturbances to Market and Household Technologies

The presence of both sources of disturbances produces interesting results (summary statistics are in the right panel of table 3). The standard deviations of market consumption and market hours are lower than in the previous case and that of output rises towards realistic levels. Trade variables continue to vary too little, even if net exports display the desired volatility. We also find high positive domestic correlations of consumption, hours, productivity and investment with output but, quantitatively, the correlations are not as close to one as in the benchmark model. Trade variables are also better behaved, at least qualitatively, with imports being more procyclical than exports and with net exports being countercyclical. Quantitatively, the cyclicality of these variables is lower than in the benchmark model.

The most evident improvement over previous specifications appears in international comovements. The model is able to reproduce the high saving-investment correlation, the output-consumption-productivity relationship and, with the specification S2, it produces positive cross-correlations of investment, labor, imports and exports, features that a model driven only by shocks to the market technology finds difficult to replicate.

The dynamics of this version of the model are displayed in the right panel of figure 3.1. Positive shocks to both domestic technologies result in a transfer of resources to the production of the investment good and the household good, with a subsequent drop of domestic market consumption. In the foreign country such a combination of shocks causes an initial transfer of investment resources to the domestic country, a decrease in the production of the household good and an increase in the consumption of the market good. Depending on the correlation and spillover of shocks, these movements may be more or less persistent but even in the case of purely idiosyncratic shocks (case S1), the cross-country correlation of consumption is low.

If no household sector was present shocks to market technology in one country would produce small cross country output correlations because investment and hours move in opposite directions in the two countries (see left panel of figure 3.1). The presence of the household sector partially reduces this negative correlation. Domestically, the initial rise in market hours and output due to shocks to the market technology is tempered by the decrease in market hours and output created by shocks to the household technology. In the foreign country the increase in market hours and output due to domestic household production shocks exceeds the decrease in market hours due to domestic market production shocks. Therefore, output and hours across countries will track each other better.

When the household sector is present there will also be an initial increase in investment in the home country but the differences across countries will be smaller relative to the two previous models. This is because the relative changes in market productivity across countries will be smaller. Hence, after a few periods both investment paths smoothly converge to their steady state from above and this induces positive cross country investment correlations. Finally, cross-country import correlations and export correlations are positive. This is because initially the increase in investment boosts capital imports, and shortly afterwards, the improvement in the terms of trade and the rise in foreign consumption promotes exports. Afterwards, the increases in domestic consumption and foreign investment create opposite flows.

In conclusion, a model with both shocks is able to replicate important cross country correlations among major macro variables. In addition, in agreement with Stockman and Tesar (1994), we find that the performance of a model with both a "supply" and a "demand" shock is qualitatively as well as quantitatively superior to one where only "supply" disturbances exist.

## 3.5 Sensitivity Analysis

In this section we investigate whether the introduction of asymmetries in the processes for the technological disturbances alter the basic conclusions we have reached. In addition, we explore the robustness of the outcomes with respect to three sets of parameters: those describing the stochastic process for technological disturbances, those concerning the household technology and those measuring the extent of foreign trade. The statistics we are concerned with are those for which a model with household production substantially improved over a model with only market production, i.e. the volatility of output, consumption, investment and employment, and the cross-country correlations of output, consumption, employment, investment, productivity, imports and exports. Domestic correlations with output are broadly insensitive to changes in these parameters and are therefore neglected in this section. In all cases the remaining parameters are those of the version of the model with both household and market disturbances.

### 3.5.1 Asymmetries in the Disturbances

We have conducted seven experiments with asymmetric disturbances. In experiments 1 and 2 (E1 and E2) country one disturbances are almost twice as volatile as country two disturbances, approximating a situation where country two faces lower 'risks' than the other. Experiments 3 and 4 (E3 and E4) consider one-way spillovers, mimicking the case where one country is substantially larger or more influential than the other. In experiment 5 (E5) we introduce asymmetric one-way spillovers which are stronger in the market technology. Experiment 6 (E6) explores the case of two-ways spillovers in the household technology and experiment 7 (E7) the case of one-way spillovers in the household technology. The exact specification of the process for the disturbances appears in the appendix. Simulation results are presented in table (3.2).

In general, the results obtained in these 7 experiments are similar to those obtained with a symmetric process for the disturbances and, if anything, the performance of the model worsens in some of the cases. There are four features of the results which deserve some attention. First, asymmetries do not significantly influence output volatility. In almost all cases the standard deviation of output is between 2.0-2.2 and only in experiment 5, where there are one-way spillovers which are stronger in the market technology, we obtain a value of 2.77. Second, with one-way spillovers, the savings-investment correlation slightly lowers for the home country (the larger one), and slightly rises in the foreign country. Although the magnitude of the effect is small in all three experiments, it goes against the existing empirical evidence (see e.g. Baxter and Crucini (1993)). One reason is that with asymmetric spillovers we drive a wedge between domestic savings and investment: domestic investment does not benefit anymore from the induced increase in foreign investment because of asymmetries while domestic savings inherits the properties of output and consumption which are only mildly affected by the presence of asymmetries. Third, the risk sharing properties of the model are affected by the presence of one-way spillovers in both sectors (experiment 4). When two-way spillovers are present output paths track each other very closely. With one-way spillovers the output changes are asymmetric and this reduces output correlations even below the consumption correlations. For the same reason cross country investment correlations are negative in this experiment. Fourth, when spillovers occur only in the household technology the model behaves as if there were only disturbances to the household production.

To conclude, apart from the case of one-way spillovers, the qualitative implications of the model are robust to the presence of asymmetries in the processes for the disturbances. Moreover, such asymmetries do not improve its qualitative performance in the dimensions of interest.

### 3.5.2 Disturbances to the Market Technology

Because the stochastic process for technological disturbances is not tied down to the data we next examine the robustness of the results to variations in persistence and in the contemporaneous spillover parameters. The results of the investigation are reported graphically in figure 3.2.

- **Persistence of the Shocks**

More persistent shocks increase the volatility of output and investment and lead to lower cross country output, labor and investment correlations since it takes more time to compensate the productivity differentials induced by idiosyncratic disturbances. Imports become more highly correlated with output and investment when shocks are more persistent because, initially, imports will be in the form of capital goods. The cross country correlation of trade variables goes to zero as the persistence of the shocks increases and becomes negative for values of the persistence parameter close to one.

- **Contemporaneous Spillover of the Shocks**

Increasing the spillovers should have approximately the opposite effect of increasing persistence since with higher contemporaneous spillovers productivity differentials are more rapidly eliminated. Volatility measures are unaltered by changes in the spillover parameters except for investment whose standard deviation decreases as the size of the spillovers increases. This is because larger spillovers make the reallocation of resources across sectors less frequent.

When no spillovers are present, a household disturbance causes domestic market consumption to decrease while household consumption and investment increase. The opposite occurs in the foreign country. With large spillovers consumption paths will track each other more closely because the initial drop in domestic consumption, induced by sectoral productivity differentials, is short lived. The effect on investment is the opposite and for higher values of the spillover parameter the correlation across countries becomes negative as in the benchmark model. The cross country correlations of output, hours and trade variables, on the other hand, are non-monotonically related to the contemporaneous spillover parameter.

In conclusion, the qualitative properties of the model are insensitive to alternative specifications of the stochastic process for technological disturbances and only extreme values of the persistence parameter (greater than 0.9) or the contemporaneous spillover parameters (greater than 0.1) modify the essence of the results.

### 3.5.3 Household Production Parameters

Figure 3.3 graphically displays how the basic statistics change for different values of four parameters affecting household production: the elasticity of substitution between market and household goods, the capital share in the household production function, steady state hours in the household technology, the contemporaneous correlation of market and household disturbances.

- **Elasticity of substitution between market and household goods.**

This parameter measures the willingness of agents to move resources across sectors: the closer is $e$ to 1, the greater is the level of substitutability. The volatilities of output, consumption and employment remain stable for values of $e$ up to 0.9 but raise dramatically when $e = 1$ and the opposite occurs for investment. The increase in volatilities of output, consumption and employment as $e$ approaches 1 is due to the more frequent transfer of resources across sectors while the reduction in the volatility of investment is due to the already discussed stabilizing effect that household production has on this variable.

With low values of $e$ the international correlation of investment is about 0.5. As $e$ increases, the instantaneous response of investment to a household production shock is larger, the convergence to the steady state is slower and this lowers the cross country investment correlation which reaches negative values for $e$ close to one.

Cross-country consumption correlations are non-monotonically related to the elasticity of substitution. For small values of $\epsilon$ the cross-correlation is high, as in the benchmark model. When the substitution effect dominates the divergences of consumption paths across countries becomes larger and the cross country correlation decreases. However, for very high levels of substitution the correlation rises again. The combined effect of shocks on consumption and investment makes the cross country correlations of outputs, imports and exports covary positively with $\epsilon$.

- **Capital share in household production function.**

As this share increases employment fluctuations contribute less to output variability and fluctuations of capital across sectors acquire a dominant role.

As the share of capital in the household sector increases the volatility of investment decreases since shocks that reallocate resources between investment and consumption will also generate a higher need for capital in the household sector. These shocks also make cross country investment correlations higher since investment paths will be more similar. As the share of capital increases, foreign investment decreases more and market consumption decreases (increases) more in the home (foreign) country so that cross country consumption correlations are lower. Finally, changes in this parameter have almost no effect on cross country output correlations and on the volatilities of output and hours.

- **Steady state hours in the household technology.**

Increasing steady state hours devoted to household activities should have approximately the same effect of increasing the share of capital in the household technology since in both cases the importance of the household sector in the economy increases. We experimented within the range [0, 0.36], which includes the value of 0.12 estimated by MRW (1993).

As expected, the more important is the household sector, the lower is the volatility of investment while no changes are evident in the volatilities of other variables. The qualitative pattern of international comovements remains robust to changes in the number of steady state household hours. Quantitatively, the cross-country correlation of labor, output, imports and exports increase and cross-country consumption correlations decrease as the importance of the household sector increases.

- **Contemporaneous correlation of household and market disturbances.**

The contemporaneous correlation of market and household disturbances is a measure of the technological incentive to shift resources across sectors. The higher the correlation is, the lower is the incentive to shift resources across sectors, and hence, the lower is the importance of the household sector in the economy. The results of these experiments confirm previous outcomes: the more is important the household sector, the smaller is the volatility of investment and the larger is the volatility of market output. In addition, lower values of this correlation produce higher cross-country correlations of output, investment, hours, productivity, imports and exports and lower cross-country consumption correlation.

In conclusion, the model is robust to changes in the parameters characterizing household production within a reasonable range. Only when the elasticity of substitution between market and household goods increases toward its upper limit are some of the features of the model, such as the low cross country correlations of consumption and the positive cross country correlation of investments, altered. In general, the performance of the model improves as the importance of the household sector increases.

### 3.5.4 Trade Parameters

Finally, we examine whether results are sensitive to alternative settings of the elasticity of substitution in the Armington aggregator and of the import share. The results are graphically reported in figure 3.4.

- **The elasticity of substitution in the Armington aggregator.**

BKK (1993) show that the degree of substitutability between domestic and foreign goods has important effects upon the comovements between net exports and the terms of trade in standard models. Our experiments indicate that variations of this parameter over the range [0,5] have no effect on the main qualitative properties of the model but affect the contemporaneous correlation between net exports and output and between the terms of trade and net exports. As the degree of substitutability increases, these correlations go from negative to positive, a result similar to that of BKK (1993), although the correlation between net exports and the terms of trade in our model remains negative for values of the elasticity parameter up to 3.25. Finally, as we increase the complementarity of the goods, the volatility of the terms of trade increases but the increase is not sufficient to produce values in the range of those observed in actual data.

- **Import Share**

Variations in the import share have no significant effect on the volatilities of consumption, hours and output, suggesting that the amplitude of the cycle does not significantly depend on trade. However trade has significant effects on the volatility of investment and imports.This is because positive technology disturbances increase investment. As the share of imports increases, the increase in investment becomes larger since it is easier to import capital goods. As a consequence, the volatility of imports also increases. From figure 3.4 it is clear that this increase is more marked for import shares greater that 0.25.

In general, the volatility of trade variables increases as the import share increases but even with an extreme import share of 0.45 the volatilities of imports and exports are only twice as large as the volatility of output, whereas in actual data they are about 3-4 times as large. Similarly the volatility of the terms of trade rises only to 0.4 in the extreme case of MS=0.45.

The savings-investment correlation is affected by variations in the import share. Since a country with a large import share is less dependent on domestic resources, the correlation between domestic savings and domestic investment decreases down to 0.5 in the case of MS=0.45. Because the import share is, in general, inversely related to the size of the country, our results support the observation that the correlation of savings and investment is higher for larger countries.

International comovements are also affected by the degree of openness of the countries. Increasing the import share affects the cross-country correlation of investment which becomes negative for values of MS greater than 0.25. Also, the cross-country correlation of output is positively related to the import share, revealing the fact that trade may not be decisive for the amplitude of cycles but may be very important for their international transmission. Similarly, because trade is mainly in capital goods, cross country consumption correlations decrease as the importance of trade increases. Therefore high import shares provide an additional vehicle to generate low consumption correlations in highly integrated economies.

Finally, variations in the import share have some effects on the correlation properties of trade variables. The correlation between the terms of trade and net exports still displays the same S-curve property noted by BKK (1993) and this property is robust to values of the import share in the range 0.10-0.35 while the cross country correlation of exports and imports becomes negative for values of MS in excess of 0.35.

## 3.6 Conclusions

In this Chapter we have examined the effects of introducing household production in a two-country, two-good international RBC model. We argue that household production adds several additional sources of dynamics to a model driven by market technology shocks and can rationalize otherwise uninterpretable national taste shocks which have been previously used in the literature ( see e.g. Stockman and Tesar (1994)). We show that when both technology and household production shocks are present the model is able to replicate several characteristics of international business cycles and account for previously unexplained features of the data. We also discuss whether or not the introduction of asymmetries in the driving forces of the model alter the basic conclusions obtained with a symmetric process for the disturbances and identify those parameters which may be crucial in determining the sign and the magnitude of interesting statistics.

Despite the relative success of our modelling effort there are still several aspects of the data which remain unexplained, primarily concerning the behavior of trade variables and the terms of trade. With our best specifications the second moments of imports, exports and the terms of trade are in fact still far away from those of the actual data. We believe that the introduction of additional sources of shocks, such as nominal disturbances, or the introduction of imperfectly competitive environments, either nationally or internationally, will be crucial in accounting for these aspects of international business cycles.

# APPENDIX

## BENCHMARK PARAMETER VALUES

| $\beta$ | $\delta$ | $\Pi$ | $\theta$ | $\eta$ | $e$ | $MS$ | $1/\rho$ | $a$ | $b$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.98 | 0.025 | 0.5 | 0.36 | 0.08 | 0.8 | 0.22 | 1.5 | 0.35 | 0.63 |

## PROCESS FOR THE DISTURBANCES: BASIC EXPERIMENTS

- S1: Idyosincratic shocks without spillovers.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0 |
| $AM2$ | 0 | 0 | 0 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0 | 0.007 |

- S2: Correlated shocks without spillovers.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0 |
| $AM2$ | 0 | 0 | 0 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

- S3: Correlated shocks and with spillovers.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0.088 |
| $AM2$ | 0 | 0 | 0.088 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

On the main diagonal of the correlation matrix are standard deviations, on the lower half correlations.

**PROCESS FOR THE DISTURBANCES: EXPERIMENTS WITH ASYMMETRIES**

- E1: Different volatilities of market disturbances.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0.088 |
| $AM2$ | 0 | 0 | 0.088 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.009 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.005 |

- E2: Different volatilities of household disturbances.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0.088 |
| $AM2$ | 0 | 0 | 0.088 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.009 | | | |
| $AN2$ | 0.25 | 0.005 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

- E3: One way spillovers in market disturbances.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0.088 |
| $AM2$ | 0 | 0 | 0 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

- E4: One way spillovers in both technologies.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0.088 | 0.835 | 0.088 |
| $AM2$ | 0 | 0 | 0 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

- E5: One way spillovers, stronger in market technology.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0.004 | 0.835 | 0.088 |
| $AM2$ | 0 | 0 | 0 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

- E6: Spillovers only in household technology.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0.088 | 0 | 0 |
| $AN2$ | 0.088 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0 |
| $AM2$ | 0 | 0 | 0 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

- E7: One way spillovers in household technology.

C MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.835 | 0.088 | 0 | 0 |
| $AN2$ | 0 | 0.835 | 0 | 0 |
| $AM1$ | 0 | 0 | 0.835 | 0 |
| $AM2$ | 0 | 0 | 0 | 0.835 |

CORRELATION MATRIX

| | $AN1$ | $AN2$ | $AM1$ | $AM2$ |
|---|---|---|---|---|
| $AN1$ | 0.007 | | | |
| $AN2$ | 0.25 | 0.007 | | |
| $AM1$ | 0.66 | 0 | 0.007 | |
| $AM2$ | 0 | 0.66 | 0.25 | 0.007 |

Table 3.1: Simulation results

| | Benchmark | | | Household shocks | | Both shocks | | |
|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S1 | S2 | S1 | S2 | S3 |
| STD(Y) | 1.26 | 1.26 | 1.25 | 1.11 | 1.07 | 1.77 | 1.81 | 1.99 |
| AR1(Y) | 0.64 | 0.64 | 0.65 | 0.70 | 0.71 | 0.54 | 0.66 | 0.74 |
| STD(CM) | 0.15 | 0.15 | 0.19 | 1.32 | 1.25 | 0.64 | 0.62 | 0.65 |
| STD(HN) | | | | 1.30 | 1.26 | 0.73 | 0.73 | 0.72 |
| STD(HM) | 0.56 | 0.57 | 0.55 | 0.98 | 0.97 | 0.75 | 0.76 | 0.73 |
| STD(AP) | 0.44 | 0.44 | 0.45 | 0.19 | 0.17 | 0.35 | 0.31 | 0.32 |
| STD(I) | 2.99 | 2.82 | 2.80 | 3.22 | 2.70 | 3.50 | 3.01 | 2.89 |
| STD(X) | 1.13 | 1.10 | 1.14 | 1.21 | 1.13 | 1.26 | 1.13 | 1.08 |
| STD(M) | 1.26 | 1.20 | 1.20 | 1.13 | 1.08 | 1.19 | 1.08 | 1.07 |
| STD(NX) | 0.42 | 0.36 | 0.37 | 0.76 | 0.66 | 0.87 | 0.66 | 0.62 |
| CORR(CM,Y) | 0.84 | 0.83 | 0.86 | 0.75 | 0.80 | 0.58 | 0.68 | 0.74 |
| CORR(HN,Y) | | | | -0.87 | -0.89 | -0.77 | -0.82 | -0.84 |
| CORR(HM,Y) | 0.99 | 0.99 | 0.99 | 0.98 | 0.98 | 0.95 | 0.97 | 0.97 |
| CORR(AP,Y) | 0.98 | 0.98 | 0.98 | 0.19 | 0.21 | 0.79 | 0.81 | 0.86 |
| CORR(I,Y) | 0.96 | 0.96 | 0.95 | 0.40 | 0.43 | 0.87 | 0.89 | 0.86 |
| CORR(X,Y) | -0.04 | 0.19 | 0.20 | 0.59 | 0.72 | 0.34 | 0.62 | 0.69 |
| CORR(M,Y) | 0.96 | 0.97 | 0.96 | 0.94 | 0.96 | 0.94 | 0.97 | 0.98 |
| CORR(NX,Y) | -0.66 | -0.57 | -0.54 | -0.21 | -0.16 | -0.45 | -0.33 | -0.31 |
| CORR(I,S) | 0.96 | 0.96 | 0.96 | 0.95 | 0.94 | 0.91 | 0.94 | 0.96 |
| CORR(Y,Y*) | 0.02 | 0.27 | 0.33 | 0.80 | 0.88 | 0.52 | 0.75 | 0.79 |
| CORR(CM,CM*) | 0.17 | 0.41 | 0.70 | 0.30 | 0.51 | 0.17 | 0.58 | 0.73 |
| CORR(I,I*) | -0.41 | -0.17 | -0.18 | -0.58 | -0.39 | -0.06 | 0.27 | 0.14 |
| CORR(X,X*) | -0.24 | 0.01 | 0.00 | 0.003 | 0.43 | 0.003 | 0.40 | 0.55 |
| CORR(M,M*) | -0.35 | -0.11 | -0.08 | 0.05 | 0.59 | 0.05 | 0.42 | 0.52 |
| CORR(AP,AP*) | -0.06 | 0.19 | 0.36 | -0.08 | 0.16 | 0.24 | 0.45 | 0.53 |
| CORR(HM,HM*) | 0.07 | 0.32 | 0.23 | 0.77 | 0.86 | 0.85 | 0.71 | 0.81 |

Notes: "Benchmark" refers to a model with only market production shocks. "Household shocks" refers to a model with only household technology shocks. "Both shocks" refers to the model with household and market production shocks. Specification S1 refers to idyosincratic shocks with no spillover, specification S2 to correlated shocks and no spillover and specification S3 to correlated shocks with spillover. STD stands for standard deviation, AR1 for the AR1 coefficients and CORR for the correlation coefficient.

Table 3.2: Simulation results. Experiments with Asymmetric Disturbances

| | E1 | E2 | E3 | E4 | E5 | E6 | E7 |
|---|---|---|---|---|---|---|---|
| STD(Y) | 2.28 | 2.18 | 2.01/2.32 | 2.19/2.40 | 2.77 | 2.11 | 2.09 |
| AR1(Y) | 0.72 | 0.73 | 0.71 | 0.73 | 0.71 | 0.64 | 0.65 |
| STD(CM) | 0.60 | 0.75/0.58 | 0.66/0.57 | 0.63/0.53 | 0.66/0.57 | 0.63 | 0.62 |
| STD(HN) | 0.66 | 0.79 | 0.74 | 0.74 | 0.74 | 0.75 | 0.73 |
| STD(HM) | 0.69 | 0.75 | 0.74 | 0.75 | 0.74 | 0.77 | 0.76 |
| STD(AP) | 0.35 | 0.33 | 0.33 | 0.31 | 0.33 | 0.3 | 0.31 |
| STD(I) | 2.83 | 3.06/2.73 | 2.74 | 3.02/3.61 | 2.74/3.28 | 3.09 | 3.24/2.93 |
| STD(X) | 1.15 | 1.08 | 1.38 | 1.38/1.02 | 1.38/0.86 | 1.18 | 1.18 |
| STD(M) | 1.04 | 1.09 | 1.02 | 1.12 | 1.03 | 1.14 | 1.14 |
| STD(NX) | 0.66 | 0.62 | 1.16 | 0.89 | 0.84 | 0.75 | 0.75 |
| CORR(CM,Y) | 0.74 | 0.66/0.85 | 0.69/0.72 | 0.73 | 0.69 | 0.68 | 0.66 |
| CORR(HN,Y) | -0.84 | -0.79 | -0.82 | -0.84 | -0.82 | -0.83 | -0.82 |
| CORR(HM,Y) | 0.97 | 0.96 | 0.96 | 0.97 | 0.96 | 0.97 | 0.97 |
| CORR(AP,Y) | 0.89 | 0.80/0.90 | 0.83 | 0.82/0.90 | 0.83 | 0.80 | 0.80 |
| CORR(I,Y) | 0.87 | 0.81/0.90 | 0.84 | 0.85 | 0.84 | 0.89 | 0.87 |
| CORR(X,Y) | 0.71 | 0.68 | 0.69/0.58 | 0.51/0.39 | 0.68 | 0.53 | 0.51 |
| CORR(M,Y) | 0.97 | 0.98 | 0.95 | 0.94 | 0.95 | 0.96 | 0.96 |
| CORR(NX,Y) | -0.49 | 0.41 | 0.50 | 0.26 | 0.49 | 0.24 | 0.22 |
| CORR(I,S) | 0.96 | 0.97 | 0.93 | 0.90 | 0.93 | 0.92 | 0.93 |
| CORR(Y,Y*) | 0.78 | 0.78 | 0.77 | 0.66 | 0.76 | 0.71 | 0.70 |
| CORR(CM,CM*) | 0.73 | 0.70 | 0.66 | 0.68 | 0.66 | 0.61 | 0.57 |
| CORR(I,I*) | 0.15 | 0.12 | 0.18 | -0.10 | 0.17 | 0.23 | 0.19 |
| CORR(X,X*) | 0.55 | 0.54 | 0.45 | 0.18 | 0.44 | 0.25 | 0.24 |
| CORR(M,M*) | 0.51 | 0.51 | 0.45 | 0.21 | 0.44 | 0.3 | 0.29 |
| CORR(NX,NX*) | -0.76 | -0.72 | -0.84 | -0.87 | -0.84 | -0.82 | -0.83 |
| CORR(AP,AP*) | 0.54 | 0.53 | 0.48 | 0.48 | 0.48 | 0.44 | 0.44 |
| CORR(HM,HM*) | 0.80 | 0.80 | 0.77 | 0.67 | 0.76 | 0.64 | 0.63 |

Notes: The rows with two numbers represent those cases where the moment for the domestic country is substantially different from the moment for the foreign country. In E1 we have different volatilities in the market disturbances, in E2 different volatilities in household disturbances, in E3 one way spillover in market disturbances, in E4 one way spillover in both technologies, in E5 one way spillover which are stronger in the market technology, in E6 spillover in the household technology, in E7 one way spillover in the household technology. STD stands for standard deviation, AR1 for the AR1 coefficients and CORR for the correlation coefficient.

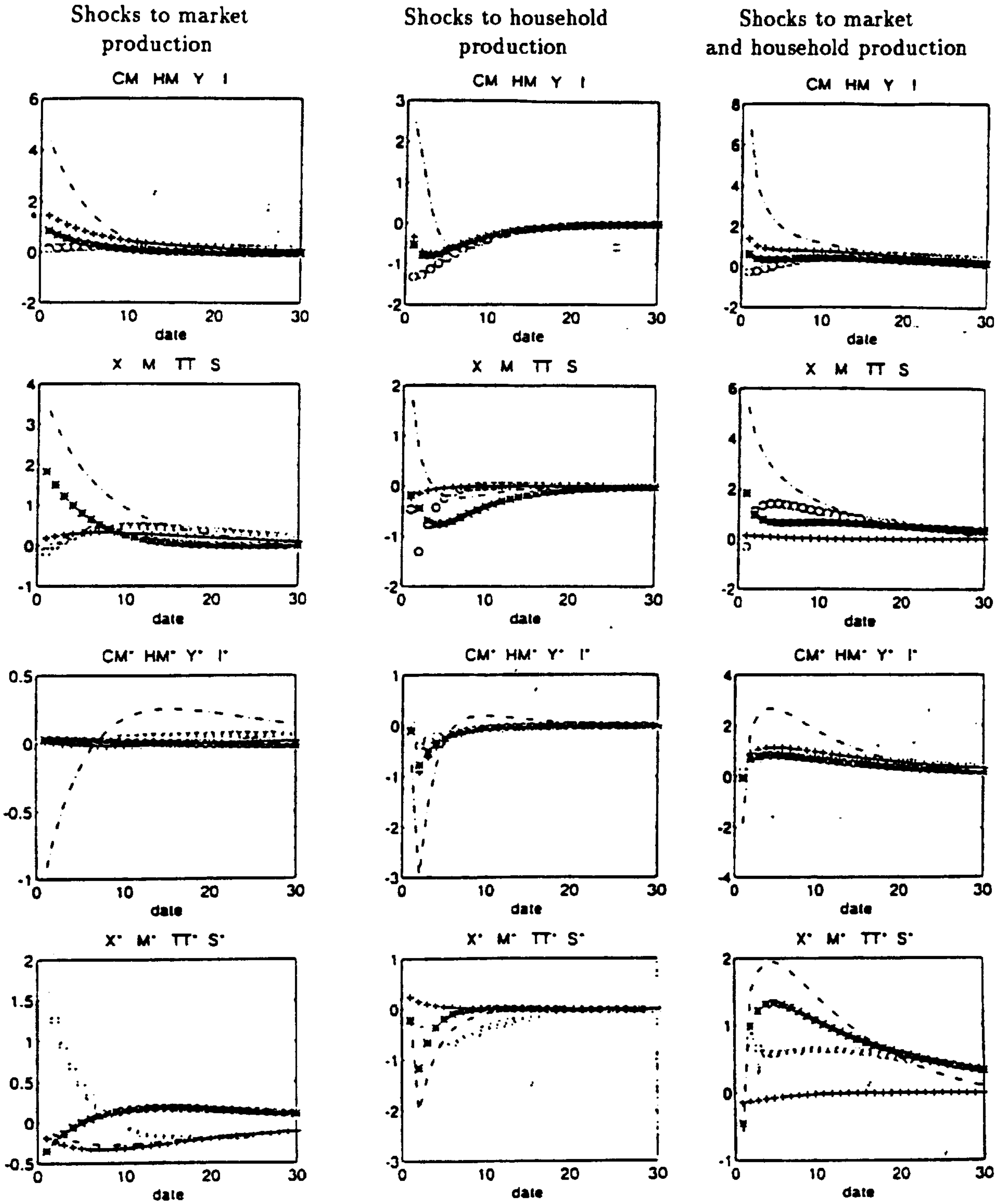


Figure 3.1.- The left column shows impulse responses to a shock to the market sector, the center column impulse responses to a shock in the household sector, the right column impulse responses to both shocks. In all the cases the specification of the shocks corresponds to model E3, in which there are spillovers and correlated shocks. CM(o) is market consumption, HM(*) are market hours, Y(+) is output, I(.) is investment, X(o) are exports, M(*) are imports, TT(+) are terms of trade and S(.) are savings. A * denotes foreign variables.

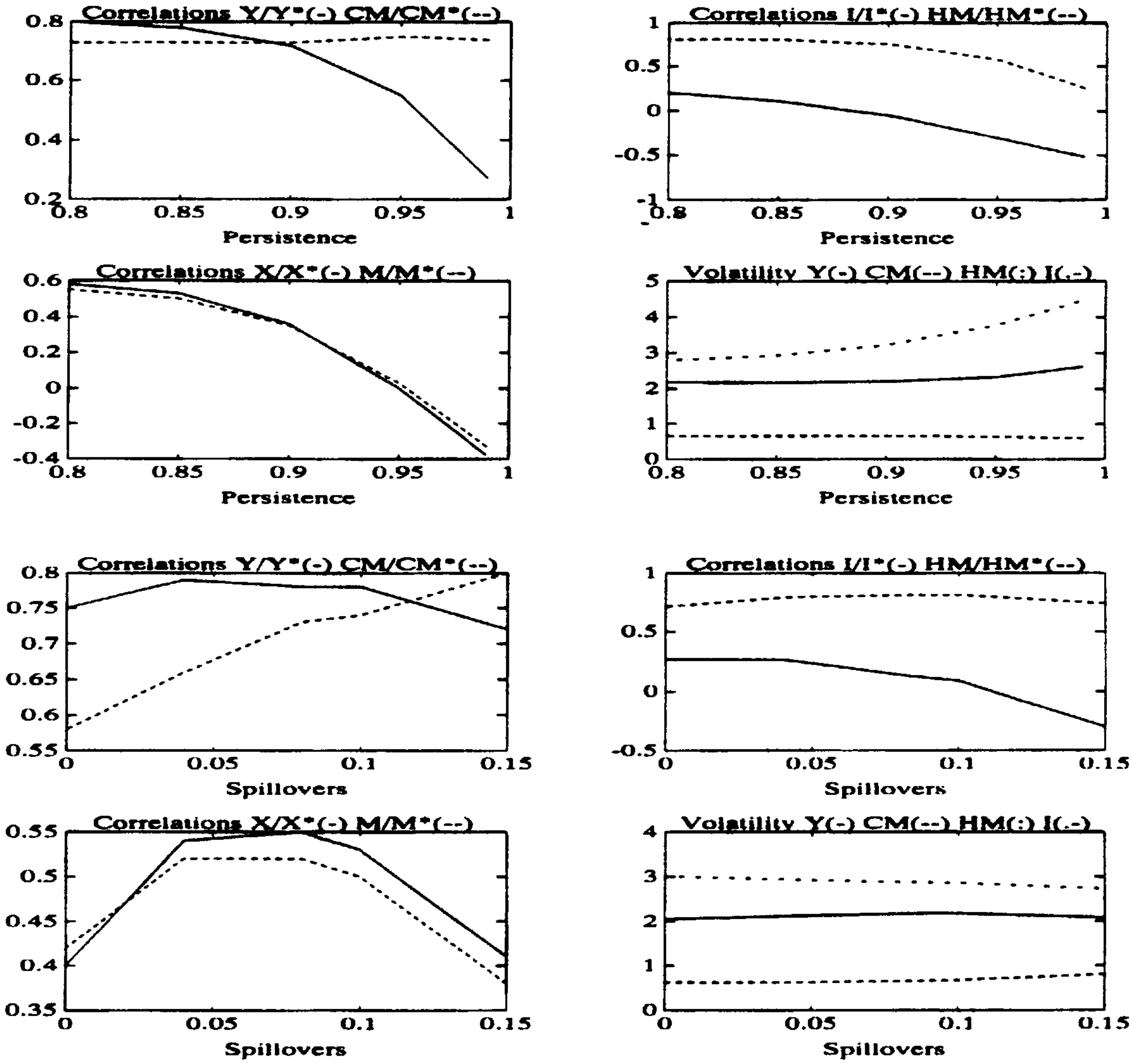


Figure 3.2: Sensitivity analysis. Experiments with the parameters of the technological process, persistence of the shocks (top portion) and spillovers (bottom portion). A * denotes foreign variables.

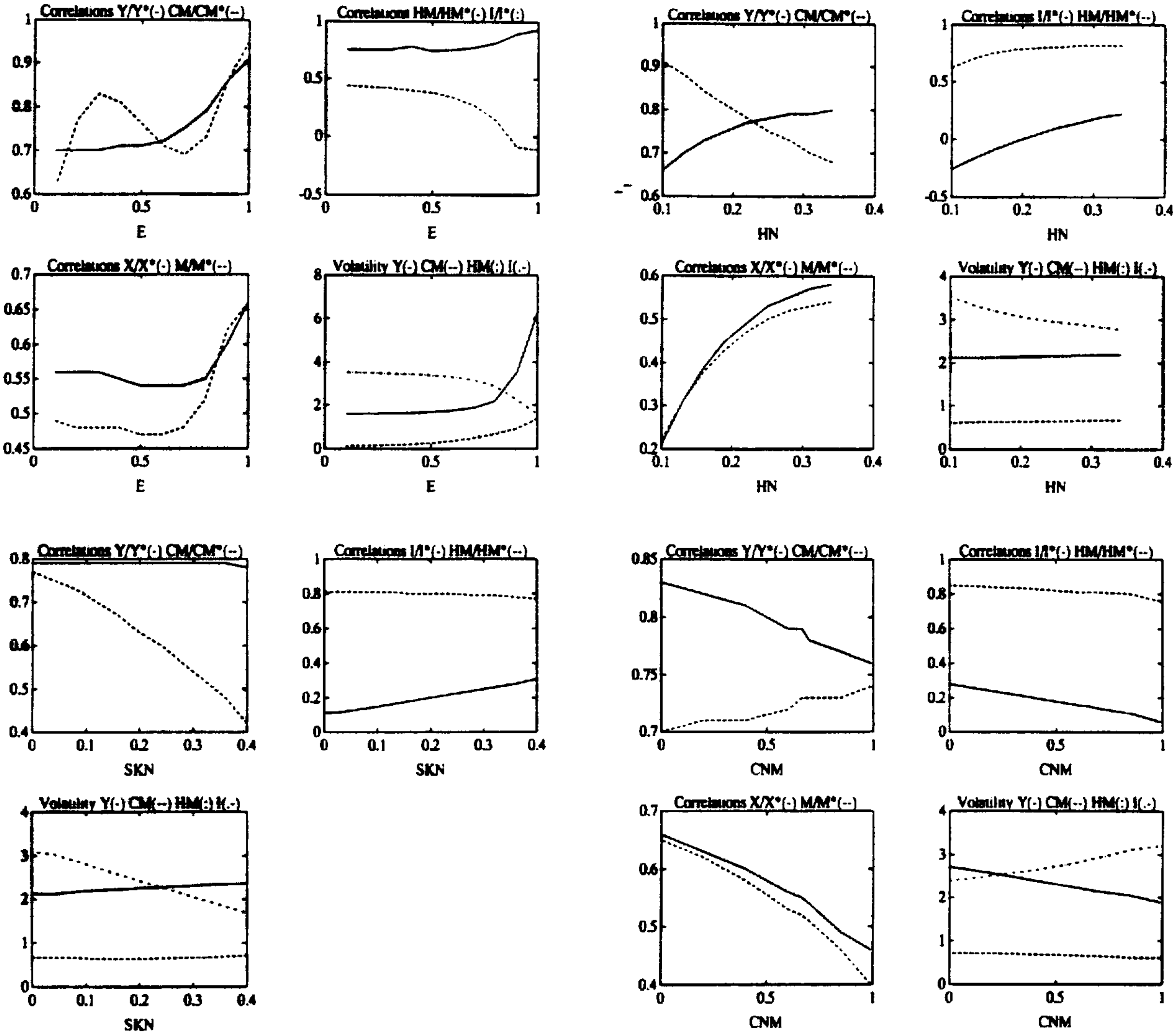


Figure 3.3: Sensitivity analysis. Household production parameters. The higher part of the left panel shows the experiments with the elasticity of substitution between home and market goods (E) and the lower part the experiments with the share of capital in the home production function (SKN). The right panel displays the experiments with the steady state number of hours at home (HN) and with the intracountry correlation of the shocks (CNM). A * denotes foreign variables.

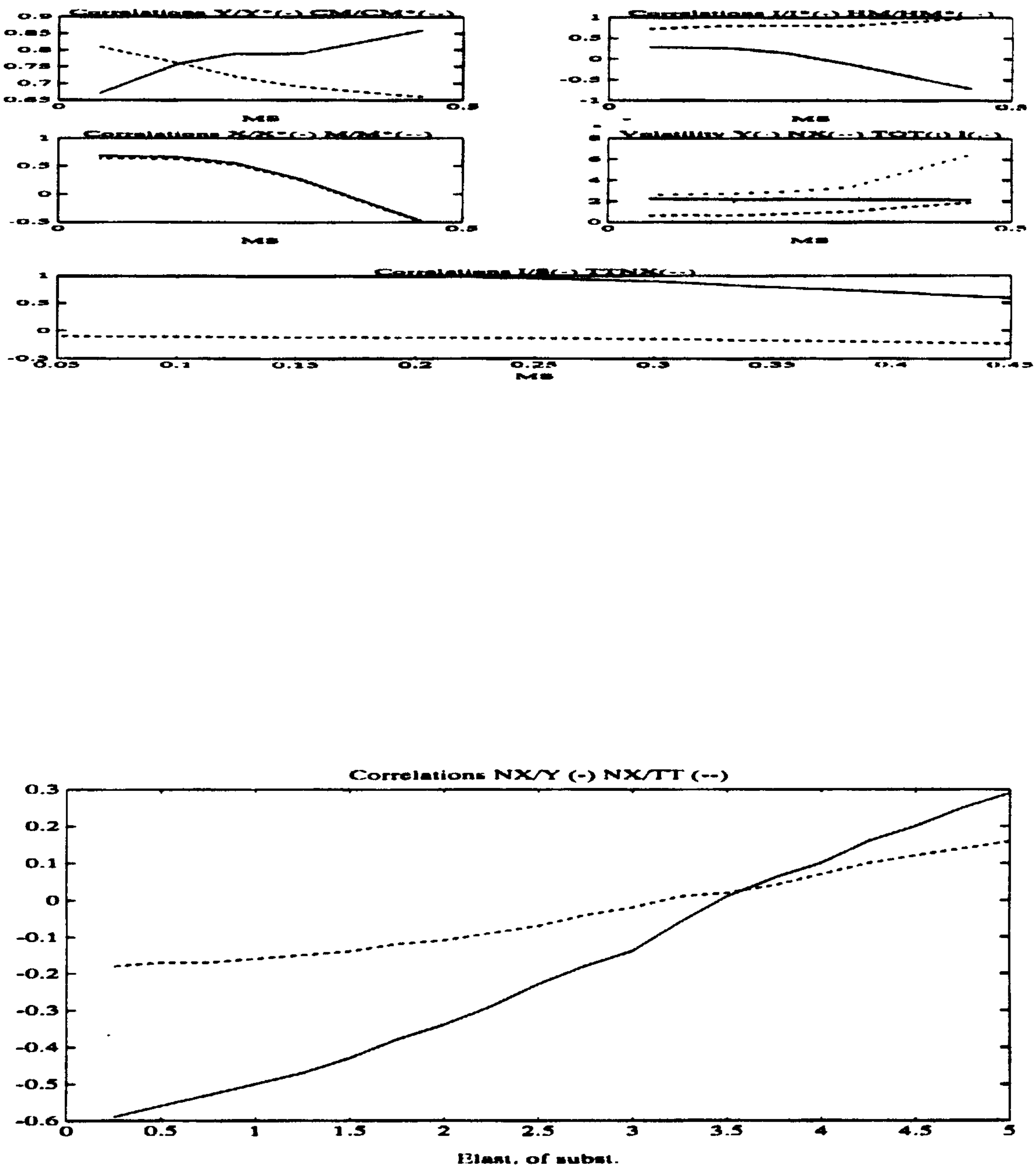


Figure 3.4: Sensitivity analysis. Foreign trade parameters. The higher part shows the experiments with the Imports share (MS). The lower part shows the experiments with the elasticity of substitution in the Armington aggregator. A * denotes foreign variables.

# Chapter 4

# Risk Sharing*

## 4.1 Introduction

The degree of international capital market integration achieved by capital flows remains a matter of debate after 20 years of the assumed internationalization of the world economies (documented in, for example, OECD (1987) or Mathieson and Rojas Suarez (1990)).

The importance of this issue is twofold. First of all, free capital mobility is in general a necessary condition for the efficient international allocation of world's savings. In complete competitive markets, welfare enhancing trade will take place continuously over time in response to the arrival of new information, and that will induce the allocation of savings to the investments with highest returns and the prevention of arbitrages. This implies the departure from the equality of savings and investments that must hold in a closed economy.

Second, free capital mobility is crucial as an insurance mechanism against unforeseeable shocks. In the financial side of the economy, free capital mobility allows the agents to diversify their portfolio and hence maximizing returns while minimizing risks. Purely financial transactions account for a big part of the trade in capital markets, but an important dimension of trade in these markets is represented by the net exchange of financial assets for current consumption. At a national level, this exchanges will be reflected in the net capital flows in the balance of payments. Besides, capital account transactions may contribute to the international sharing of consumption risks, since they permit individual countries to smooth their consumption over time by issuing claims to overcome transitory shortfalls in domestic output or increases in domestic investment, serving as the insurance mechanisms in the real part of the economy. Therefore, an economy with perfect capital mobility and hence where the consumption risk sharing proposition will be binding, implies that individual agents, countries at a national level, will not react in response to idiosyncratic shocks, and will react to common shocks only to the extent that reacts the aggregate.

This issue of international consumption risk sharing becomes more important as the degree

*This Chapter is a revised version of Ubide (1994).

of integration of the economies increases. In closed economies, the international transmission of shocks is neglectable by definition, as it is in open economies where each individual country is able to offset a shock through suitable policy action. In more integrated economies this may no longer be true, since the degree of policy independence may often decrease with integration. For example, in a fixed exchange rate agreement, monetary policy autonomy disappears and the scope for fiscal policy may also be limited. Within a system such as the future European Monetary Union, if the market does not naturally provide it, some provision should appear in order to ensure the desired degree of consumption risk sharing and protect individual countries in difficulty since, as Sala-i-Martin and Sachs (1992) and many others suggest, it may be critical for the successful implementation of a common currency.

Beyond this direct interest on the risk sharing proposition the presence and strength of consumption insurance has methodological implications for macroeconomics and finance. Full consumption insurance implies the existence of a representative consumer, that is, a social welfare function defined over aggregates that is independent of changes in the distribution of income or wealth over time. A rejection of insurance suggests that there may be important relations between distributions of income or consumption and we should take into account models with atomistic private sector.

Given the importance of the issue of international capital market integration, a huge amount of literature has been developed in order to evaluate the degree of integration of the markets, applying the first two characteristics of integrated capital markets that we have examined below: the allocation of savings and investments and the comparison of rates of return and diversification of portfolios. Instead, the third characteristic, the sharing of risks in consumption, has only been developed recently at a macro level, analyzing G7 countries (see, i.e. Canova and Ravn (1993) or Obstfeld (1993)).

In this Chapter we enter the debate of whether the EU has reached the desired degree of market integration by analyzing the consumption risk sharing properties of the european space. We analyse the different approaches to the study of financial integration in Section 4.2 in order to provide a framework in which to encompass our study. Since it is one of the main properties of neoclassical models, we use a multicountry version of the neoclassical growth model to theoretically derive the international consumption risk sharing proposition, that is the equalization across countries of the marginal rates of substitution in consumption (Section 4.3). We show that if we allow for heterogeneous countries the conclusions drawn from standard tests may be misleading.

This Chapter contains a methodological advance over earlier work. In general, the existing papers test for risk sharing by computing correlation coefficients of consumption series, typically without standard errors. This evidence is far from being conclusive, and in any case it can only be interpreted as contemporaneous evidence. Our empirical investigation in Section 4.4 will be more complete and will have four parts. Given that risk sharing is widely investigated in Real Business Cycle models, we provide correlation coefficients in order to compare with existing literature. Then, we investigate our theoretically developed conditions in two setups, static through regression analysis and dynamic through impulse response and variance decomposition analysis in VAR systems. This new empirical dynamic specification allows us to test the intuition that lies behind the risk sharing proposition, that is common responses to common shocks and no responses to idiosyncratic shocks. The coefficients of a system of Seemingly Unrelated Regressions in the static case and the amount of variance not due to the shocks in the variance decomposition analysis are presented as informal measures of average risk sharing in Europe. Finally, we allow for the posibility of lagged risk sharing by testing for Granger-causality in the VARs and discuss the problem of distinguishing risk sharing from autarky.

There are some results standing out from our analysis. The first one is that the degree of risk sharing is high in the EU, around 50 % within a year and 60-70% within five years, but with differences across countries. We can distinghuish between a 'core' and a 'periphery', but with a grouping of countries different from that of Bayoumi and Eichengreen (1992). Their analysis is based on the identification of the shocks that affect the countries whereas ours is based on the response to these shocks. Belgium, Luxembourg and The Netherlands are the countries with highest degree of risk sharing and together with Germany and the UK could form the 'core' of the Union. France, Ireland, Portugal, Greece and Spain are the countries with less amount of risk shared within the EU, being Portugal the closest country of the panel. Portugal, Greece and Spain have been relatively closed countries, at least with respect to Europe, in the last 20 years, and Ireland is perhaps more conected with U.K. than with Europe. Finally, Denmark and Italy are another group, since it seems that Denmark is an open country but that it is not sharing its risks within the EU and Italy, despite being an historical member of the EU, displays such variablity in its macrovariables that is relegated to the periphery. Therefore, although individually this group of countries are supposed to have open capital markets, it is not clear that they have reached the desired degree of integration amongst them so as to form a monetary union.

It seems from the evidence that the existing institutions and arrangements are providing a good degree of risk sharing and that no other specific implementation is needed. Likewise, the degree of market integration that exists in Europe does not seem to be perfect and some welfare gains can be expected from the further opening of capital markets. Moreover, policy measures seem to be needed to solve the structural divergences that we have found related to the reactions of the different countries to idiosyncratic variables, but it is to be noted that this issue should be related with institutional redesign and redistribution of income and not with specific insurance programs.

## 4.2 How can we measure capital mobility

Since the 1970's, the world financial markets have clearly become global. Both the widespread financial deregulation and modern communication technologies have created close linkages among the financial markets of the industrialized countries.

Capital becomes mobile between two regions if some of their residents are able to engage in inter-regional asset trades. Thus, the degree of capital mobility is measured by the scope of such trades, that will in practice be limited by transaction costs, taxes and specific regulations.

It is important to understand that the degree of capital mobility cannot be measured by the total size of net capital flows, either in absolute value or relative to gross national products. Large capital flows can take place in perfectly integrated markets, as well as in segmented markets, and investment can be perfectly allocated even without any capital flow. Dornbush (1980) defines perfect capital mobility as the combination of perfect substitution of domestic and foreign bonds and the instantaneous adjustment of actual and desired portfolios. However this definition only takes into account trade in safe nominal assets while considering the possibility of trading risky assets, Stulz(1986) defines capital mobility as being perfect if, in all the states of the world, all investors value identically in some given numeraire any arbitrary cash flow irrespectively of where it originates.

There have been two main approaches in the literature to the issue of determining the mobility of international capital.

The first one is based on the direct comparison of national saving and domestic investment rates based on the fact that in a closed economy, savings and investment must be equal. Feldstein and Horioka (1980) initiated this approach based on the idea that the degree of correlation between saving and investment rates can serve as a barometer of the degree of capital mobility of an economy.

The second one, more indirect, derives from the equilibrium condition that results from maximizing utility in neoclassical growth models, and is based on the comparison of either expected returns on assets or marginal rates of substitution in consumption.

### 4.2.1 Direct measures

The difference between a country's income and its expenditure yields a direct measure of the extent of its intertemporal trade with the rest of the world. When an economy is closed, incomes have to be equal to spendings. In contrast, open economies may finance discrepancies between income and spending through international borrowing and lending.

Feldstein and Horioka (1980) and Horioka (1983) initiated this approach attempting to measure these discrepancies based on the assumption that in a world with perfect capital mobility movements in domestic investments and movements in national savings will be approximately uncorrelated. Their analysis is based on regressing

$$(I/Y)_i = \alpha + \beta(S/Y)_i + \epsilon_i \tag{4.1}$$

on a cross-section of OECD countries. They obtained an estimate of $\beta$ of 0.887 and the authors conclude that capital mobility is not perfect since the estimated value of $\beta$ is interpreted as measuring the effect of a sustained increase in a country's savings rate on its investment rate. However, recent research in the fields of endogenous growth and real business cycles has obtained similar values of this parameter in models with perfect capital mobility (see among many others

Obstfeld(1992) or Baxter and Crucini(1993)) and therefore it seems that this direct relationship between savings and investments and capital mobility is not that clear.

### 4.2.2 Indirect measures

These attempts make use of the results of simple two-good models of international nominal interest rate differentials with risk averse investors, of the type developed by Breeden (1979) or Lucas (1978). If there is one asset in an economy with complete capital markets and representative agents, intertemporal maximization of the utility yields an equilibrium condition

$$E_t[Q^i_{mt+1} R^j_{t+1}] = 1 \tag{4.2}$$

where R is the return on the asset and Q the marginal rate of substutition of money, and it has to hold for every asset traded (j) and for every consumer (i).

#### Rates of return-based tests

Setting $i$ fixed, a representative agent say in Spain, for example, we can use this equality as the basis for empirical exercises trying to analyse the degree of capital mobility, by comparing the yields on equivalent assets in different places.

The most straightforward approach would be the direct comparison of rates of return on physical capital in different countries. Although there have been some attempts (Harberger (1978)), the problems of measurement or different tax treatments make it very difficult to compare it properly. Hence, most of the research has gone to a more restrictive group of homogeneous financial assets, and even here the different taxation of interest payments may include some biases in the results.

We should notice that if we make the comparison between assets traded in different currencies but in the same place (for example, London Eurocurrency deposit rates) we will be testing the forward foreign exchange premium but the results will be uninformative about capital mobility. Hence, the relevant variables to use would be nominal yields on "on-shore" and "off-shore" assets denominated in the same currency. These rates generally do differ, quite expectably if you take into account cross-country heterogeneity as measured by default risk, sovereign and political risk and capital controls and other financial regulations. Frenkel(1993) reports these tests for a wide range of industrialized and developing countries for the period 1982-1988 concluding that in general short-term covered interest differentials were small and hence that there seems to be a substantial degree of capital mobility among OECD countries that has increased since the early 70s (see also Obstfeld (1986b)).

However, despite the fact that the markets are assumed to be fairly well integrated in the real world, several studies have found that the portfolios of developed countries are biased towards domestic assets(e.g. Golub (1991) and Tesar and Warner (1992)), that there are predictable excess returns (Solnik, 1991) and there is a vast room for diversification in the financial markets (e.g. French and Poterba (1991) or van Wincoop (1992)). There have been several explanations for this apparently irrational behavior, that may include the existence of nontradable goods (Stockman and Dellas (1989)), the differences in relative risk aversion across countries (Canova and Ravn (1993)), the existence of frictions such that transaction costs or taxes that may wipe out the benefits from diversification (Cole and Obstfeld (1991) and Obstfeld (1992a)), or the presence of informational costs about the future payoffs of international investments (Backus and Kehoe (1992)) or particular investor choices (French and Poterba, 1991). [2]

**Consumption-based tests**

We have examined the existence of risk sharing using tests based on financial variables. But we can also fix $j$ in equation 4.2 and test for the same asset for representative agents in different countries. This will lead us to consumption-based tests which examine countries participation in world financial markets.

This implies that the emphasis of risk diversification can be shifted from financial to real variables, and this brings us to the issue of international consumption risk sharing. Complete insurance implies that the consumption of agents will not vary in response to idiosyncratic shocks while risk diversification in financial markets implies that the value of a well diversified portfolio will not vary due to an idiosyncratic shock to a particular currency. Cochrane (1991) defines perfect risk sharing as the cross-sectional counterpart of the permanent income hypothesis, since the latter implies that the consumption of an individual will not vary over time in response to idiosyncratic transitory shocks.

You will find full consumption insurance if financial markets are complete or there are a set of institutions making the role of a central planner implementing Pareto optimal allocations. However, even when financial markets are not complete, Pareto optimal allocations can be obtained if there is continuous trading of a few long lived securities (Duffie and Huang (1985)). Also, you could achieve close to full consumption insurance without complete markets or institutional intervention as long as agents have similar preferences and differ only on their income stream (Baxter and Crucini (1992) and Marcet and Singleton (1992)).

Theoretical analyses of these issues appear in several kind of models and with different treatments. In models of closed economies where there is income heterogeneity across agents (Mace, 1991) or related to the issue of precautionary savings (Guiso and Jappeli (1992)). It arises also with open economies, where countries with heterogeneous income streams trade internationally in order to avoid country specific risks and only bear aggregate world-wide risk (Brennan and Solnik (1989), Backus, Kehoe and Kydland (1992) or Ravn(1993)). Finally, it arises also in endogenous growth models (Obstfeld (1992b)).

Empirical analysis of international consumption risk sharing generally reaches the conclusion

[2] So far we have compared nominal interest rates. No much has been done about real interest rates, since the underlying theory is based on very strong assumptions which are very difficult to accept in practice: uncovered interest parity and purchasing power parity, which are always rejected in empirical tests (see, for example, Cumby and Obstfeld (1984) and Cumby and Mishkin (1985)).

that markets for risk function imperfectly at the international level, and certainly less efficiently than they do at domestic or individual level. Atkeson and Bayoumi (1992), for example, argue that the national diversification of regional incomes within the United States is significantly greater than the international diversification of European national incomes. Other examples along these lines could be Van Winkoop (1992), that examines the degree of risk sharing evident in Japanese regional consumption data or Sala-i-Martin and Sachs (1992) that present evidence on the amount of risk borne by the central institutions in the United States. This fact of imperfect risk sharing is specially true for less developed countries, where both institutions and markets are less developed and where the access to international capital markets is more problematic, and hence the borrowing opportunities are smaller for reasons of moral hazard and country-specific risk.

With an international dimension, Canova and Ravn(1993), Obstfeld(1993) and Lewis (1993) have all studied the degree of risk sharing on samples of OECD countries, concluding that the level of risk sharing has increased from 1973 but is still less than perfect. Our method and sample is different form theirs, and hence it can be undestood as a complement to existing studies. The basic message of all these works is that correlations among international consumption movements are too low to be fully explained with a model with free international asset trade and complete markets, remaining, in the words of Backus,Kehoe and Kydland (1993), one of the most presssing puzzles of the international business cycle framework.

Given this empirical evidence on imperfect risk sharing, other approaches have tried to measure the welfare loses due to imperfect risk sharing (Breenan and Solnik (1989) and Obstfeld (1992a)), analyse moral hazard issues as the reason of imperfect risk sharing (for example in less developed countries where there is credit rationing and risk of repudiation (Atkeson (1991)) or in cases where insurance is directed to country specific shocks, say, moral hazard problems manifested in labor militancy when the cost of unemployment benefits is shifted from national to federal taxpayers (Eichengreen(1991))) or set up the conditions necessary for insurance schemes (differentiating between insurance and redistribution (Melitz and Vori (1992))) and institutions to implement the desired degree of risk sharing (Persson and Tabellini (1992)).

## 4.3 A theoretical model

Following an Arrow-Debreu approach we will cast the risk sharing problem in the setting of a world social planner. Since we have a model without distortions, the outcome will be equivalent to the competitive equilibrium. The planner will maximize the weighted sum of expected utilities of the agents subject to an aggregate resource constraint. An optimal resource allocation will imply a distribution of aggregate endowments that equalizes weighted marginal utilities across agents.

In particular, this world social planner faces the problem of maximizing the utility of the representative consumer of J countries when there is only one aggregate consumption good and there is perfect trade in a complete set of state-contingent assets.

The information structure of the economy is represented by $s_{\tau t}$, $\tau = 1, 2...S$, where each $s_{\tau t}$ is an event that represents all common information at time t and collects all states of the world. S is finite, $\pi(s_{\tau t})$ is the probability that event $\tau$ occurs at time t and $\sum_{\tau=1}^{S} \pi(s_{\tau t}) = 1, \forall t$.

The expected lifetime utility of the representative consumer in country j is expressed as:

$$\sum_{t=0}^{\infty} \beta^t \sum_{\tau=1}^{S} \pi(s_{\tau t}) U[C_t^j(s_{\tau t}), b_t^j(s_{\tau t})] \tag{4.3}$$

where $C_t^j(s_{\tau t})$ is the consumption of the agent of country j at time t and event $\tau$, $0< \beta < 1$ is the discount factor common to all agents and $b_t^j(s_{\tau t})$ represents a preference shock, that may include all the factors different from market consumption that can enter the agent's utility function, like leisure, government expenditure, non tradables, household production, etc...

Each country is endowed with a stochastic amount of the good at each t, $y_t^j(s_{\tau t})$. The stochastic nature of the endowment can be represented as $y_t^j(s_{\tau t}) = \bar{y}_t^j + \mu_t^j(s_{\tau t}) + \epsilon_t^j(s_{\tau t})$, where $\bar{y}_t^j$ represents the deterministic component, $\mu_t^j(s_{\tau t})$ represent the effect of an aggregate shock and $\epsilon_t^j(s_{\tau t})$ represents the idiosyncratic shock. Aggregating over the J countries, $y_t^a(s_{\tau t}) = \bar{y}_t^a + \mu_t^a(s_{\tau t})$, since we assume that $\epsilon_t^a(s_{\tau t}) = 0$ for all events and time. The wealth of each country is represented by $\Pi_j$ (which could represent the initial condition of each country) and the population by $\chi_j$ (we will assume that the population and wealth of the countries will not change with time) and $\sum_{j=1}^{J} \Pi_j = \sum_{j=1}^{J} \chi_j = 1$.

Therefore, the world social planner will maximize the weighted sum of the expected utilities of the J countries, given by equation (4.4) by determining an allocation of consumption across countries subject to the aggregate resource constraint, equation (4.5):

$$\max_{c_t^j} \sum_{j=1}^{J} \Pi_j \sum_{t=0}^{\infty} \beta^t \sum_{\tau=1}^{S} \pi(s_{\tau t}) U[C_t^j(s_{\tau t}), b_t^j(s_{\tau t})] \tag{4.4}$$

$$\sum_{j=1}^{J} \chi_j C_t^j(s_{\tau t}) = \sum_{j=1}^{J} \chi_j y_t^j(s_{\tau t}) \tag{4.5}$$

for all events and dates, where $0< \Pi_j < 1$ and $C_t^j(s_{\tau t}) > 0 \ \forall j$. The first order conditions for this problem can be written as:

$$\frac{U'(C_t^i(s_{\tau t}))}{U'(C_t^k(s_{\tau t}))} = \frac{\frac{\Pi_k}{\chi_k}}{\frac{\Pi_i}{\chi_i}} \tag{4.6}$$

for any i and k, where $U'(C_t^i(s_{\tau t})) = \frac{\partial U}{\partial C_t^i(s_{\tau t})}$. Hence, the aggregate endowment is distributed across countries such that the weighted marginal utilities are equated across countries.

Using logarithms, the above expression can be written as:

$$\log U'(C_t^i(s_{\tau t})) - \log U'(C_t^k(s_{\tau t})) = \xi_{ik} \tag{4.7}$$

where $\xi_{ik} = \log\left(\frac{\Pi_k}{\chi_k}\right) - \log\left(\frac{\Pi_i}{\chi_i}\right)$ ,or alternatively

$$\log U'(C_t^i(s_{\tau t})) - \log U'(C_t^a(s_{\tau t})) = A_i \tag{4.8}$$

where $U'(C_t^a(s_{\tau t})) = 1/j\sum_{j=1}^{J} U'(C_t^j(s_{\tau t}))$ and $A_i = \log\left(\frac{\Pi_k}{\chi_k}\right) - \log\left(\frac{\Pi_a}{\chi_a}\right)$. Equation (4.7) implies that apart from a scale factor, the marginal utility of consumption of any two countries must be equalized. Instead, equation (4.8) states that the marginal utility of consumption of country i is proportional to the marginal utility of average world consumption, holding both propositions for all countries j, all states $\tau$ and all periods t. It is important to note that while both implications are not different, the averaging procedure makes the second one less strong than the first and hence if equation (4.7) holds then equation (4.8) will hold as well but the reverse is not true.

For all that conditions to be valid, we should select a HARA utility function (see Breenan and Solnik(1989)). Among these we will choose a CRRA specification because (see King, Plosser and Rebelo (1988c)) is compatible with balanced growth. Specifically, the utility function is

$$U[C_t^j(s_{\tau t}), b_t^j(s_{\tau t})] = \left(\frac{1}{1-\sigma_j}\right)((C_t^j(s_{\tau t}))^{\eta}(b_t^j(s_{\tau t}))^{1-\eta})^{1-\sigma_j} \text{ if } \sigma_j \neq 1 \tag{4.9}$$

$$U[C_t^j(s_{\tau t}), b_t^j(s_{\tau t})] = \eta \log C_t^j(s_{\tau t}) + (1-\eta)\log b_t^j(s_{\tau t}) \text{ otherwise} \tag{4.10}$$

where $\sigma_j$ is the coefficient of relative risk aversion of country j and $\eta$ is the elasticity of substitution between $C_t^j(s_{\tau t})$ and $b_t^j(s_{\tau t})$.

With the above specification of the utility function, equations (4.7) and (4.8) become

$$\log C_t^i - \alpha_{ik}\log C_t^k + \rho_{ii}\log b_i - \rho_{ik}\log b_k = \xi_{ik} \tag{4.11}$$

and

$$\log C_t^i - \alpha_{ia}\log C_t^a + \rho_{ii}\log b_i - \rho_{ia}\log b_a = A_i \tag{4.12}$$

where $\alpha_{ik} = \frac{\eta(1-\sigma_k)-1}{\eta(1-\sigma_i)-1}$ and $\rho_{ik} = \frac{(1-\sigma_k)(1-\eta)}{\eta(1-\sigma_i)-1}$.According to that expresions, the consumption of country i net of taste shocks will be higher or lower than that of country k depending on the sign of $\xi_{ik}$,that represents the differences of the logs of per capita wealth. Hence, countries with higher (lower) wealth per capita will consume more (less). And the same happens regarding the share of each country in aggregate consumption (equation (4.12)).

Taking the first difference of the equations, we express the international consumption risk sharing proposition in terms of the rates of growth of consumption:

$$\Delta\log C_t^i = \alpha_{ik}\Delta\log C_t^k - \rho_{ii}\Delta\log b_i + \rho_{ik}\Delta\log b_k \tag{4.13}$$

$$\Delta \log C_t^i = \alpha_{ia} \Delta \log C_t^a - \rho_{ii} \Delta \log b_i + \rho_{ia} \Delta \log b_a \tag{4.14}$$

Since they are time invariant, the welfare weights are removed by taking diffferences. The implications of these equations are that the rate of growth of consumption of country i net of preference shocks will comove with that of country k and with that of the aggregate. Hence, in a perfect risk sharing enviroment idiosyncratic shocks will not affect the consumption stream of individual countries and aggregate shocks will affect them only to the extent that the shocks affect the aggregate. An uneven response of a country to a common shock will be then evidence of imperfect risk sharing.

We should note that we have made some important assumptions in our model. First of all, we have assumed representative agents in each country, and hence that there is already perfect risk sharing within each country. Second, our specification of the utility function assumes time and state separability. Third, we have assume perfect information and complete asset markets. However, some of these problems have been already treated in the literature. Mace(1991) analyze the risk sharing conditions for exponential and power utility functions whereas Canova and Ravn (1993) extend it to issues like habit persistence, durability, more than one good traded, leisure or heterogeneous countries. Included in international real business cycle models, Canova and Ubide(1995) study the implications of the risk sharing proposition when home production is included in the utility function of the agents, Deveraux, Gregory and Smith (1992) introduce leisure choices in a non-separable way and Tesar (1994) analyses the introduction of nontradable goods. In all these cases, the only difference will be that more elements will appear in the right hand side of the equations, like elasticities of substitution (for nontraded goods or government spending) or leisure and productivity profiles (for leisure).

## 4.4 Empirical implications

This part of the work describes the results that we have obtained in our empirical research.

The empirical investigation will follow four steps. The risk sharing issue has widely arosen in RBC models, since these models predict in general a high degree of risk sharing, that means corr(C,C*)=1 when C* is the consumption of the foreign country, whereas the coefficients obtained with actual data are much lower. Hence, we will compute cross-country correlation coefficients of consumption series in order to determine the degree of risk sharing in that sense. Newey-West consistent standard errors computed with GMM give us of the statistical significance of the point estimates

In a second step, recasting the theoretical implications of risk sharing represented by equations (4.13) and (4.14), we have

$$\Delta \log C_t^i = \beta_1 \Delta \log C_t^a + \beta_2 \Delta \log \ b_t + \epsilon_t \tag{4.15}$$

and in the case of perfect risk sharing the hypothesis $H_0$: $\beta_1 = 1$ and $\beta_2 = 0$ should not be rejected. The predictions of these equations are that, regressing national consumption on aggreate consumption and any other right hand side variables that could affect national consumption, all variables other than aggregate consumption are predicted to enter insignificantly. This would reflect that fluctuations in national consumption respond to aggregate risks but not to idiosyncratic risks. The right hand side variables will be both common and idiosyncratic variables.

All the previous analyses considers the contemporaneous static implications of the risk sharing proposition. But the intuition that lies behind the theory is in some sense dynamic, since we are considering the responses of national consumption to different shocks. We attempt to introduce this intertemporal dimension through the analysis of the impulse response functions in VAR systems of each national consumption together with common or idiosyncratic shocks. With that instrument we will be able to test the implications of eqs. (4.13) and (4.14), determining whether the response of domestic consumption to a common shock in two different countries are similar and whether the response of a country is similar to that of the aggregate. Likewise, we will study the response of national consumption to different idiosyncratic shocks and check, as the theory predicts, that those response are not significantly different from zero. The variance decomposition analysis will give us a quantitative evaluation of the degree of risk sharing in this dynamic framework.

Finally, one further issue will be explored. There are countries that effectively share their risks within an aggregate but that systematically do that with some lag due to the particular structures of their economies (this could be the case of, for example, Spain). The VAR setting allows us to test this implication through Granger-causality tests, since the prediction of the theory will be then that current and lagged exogenous variables should not help in predicting the behaviour of current national consumption. Hence, we will test for Granger causality in the VARs, expecting that the exogenous variables will not Granger-cause national consumption.

### 4.4.1 Data analysis

The issue of international consumption risk sharing has been to some extent developed and tested for the main OECD countries, but it has not been applied and tested for the European Community as a whole, despite the fact that it may become extremely important for the future implementation of a common currency at the third stage of the EMS. That has lead us to set up the tests with data from the twelve countries of the EU, in an attempt to discover the peculiarities of this group of countries.

The data has been obtained from DATASTREAM, and measures annual per-capital total aggregate consumption data in 1985 prices from OECD Main Economic Indicators for the period 1960-1993 [3]. The main difficulty we face when working with EU data is that you cannot obtain quarterly data except for France, UK, Germany and Italy. But given the usually low quality of consumption data, it is more likely to find noise in quarterly than in annual data. Besides, Christodulakis et al. (1993) have analysed the stylized facts of the EU at both annual and quarterly frequencies and conclude that there is no significant difference between the two specifications. Another issue regards the definition of the consumption variable. Following the

[3]For Germany the sample is 1960-1989 in order to avoid distorsions from the effects of German unification.

theory we should use only consumption of tradable goods. However, we have found that either it is impossible to obtaine disaggregated series on consumption of tradables or the dissagregation methods across countries are quite different, a fact that could introduce distortions in the analysis. Hence, we will use total annual consumption trying to offset the fact that the series are short and include nontradables with supposedly a better quality and homogeneity of the data. A final consideration is related to the durables/non durables disaggregation. The theory would indicate the use of only non durables and services as the consumption variable, because durables provide utility during an extended period of time and therefore measured consumption may be a bad proxy for the marginal utility derived from their ownership. However, in doing so we may be introducing a bias against risk sharing, because services are in general non tradable goods whereas durables are highly tradable. A final consideration is related to the durables/non durables disagregation. The theory would indicate the use of only non durables and services as the consumption variable, because durables provide utility during an extended period of time and therefore measured consumption may be a bad proxy for the marginal utility derived from their ownership. However, in doing so we may be introducing a bias against risk sharing, because services are in general non tradable goods whereas durables are highly tradable.

A critical issue regards the unit root properties of the data. Consumption series are usually non stationary series. With this fact in mind, we have included in our model an implicit detrending procedure, since we will be working with the first difference of the series [4]. It is important to note that different detrending methods leave cycles of different lengths in the data (see Canova (1991)). First Order Differencing leaves in the data cycles of 2-3 years while, for example, Hodrick-Prescott filtering, leaves cycles of 5-6 years. This can be important when interpreting the results of our analysis, because short term divergences will be always easier to insure than longer ones.

### 4.4.2 Empirical Results

#### Correlation analysis

We start the analysis using the simplest tool that we have available, the correlation structure of the series. Unless otherwise stated, the standard errors are Newey-West consistent standard errors computed with 10 lags.

Table 4.1 displays the correlation matrix of the rates of growth of consumption for the twelve countries. The values range form zero (non significant) to 0.55. The mean values for the countries go from 0.19 for Denmark to 0.44 for Belgium. Denmark is the country with less coefficients significantly different form zero, (it is only significantly correlated with Luxembourg), together with Portugal and Spain, that are only correlated with two and three countries respectively. Belgium, Netherlands, U.K., Ireland, France and Germany seem to be well correlated amongst themselves and Luxembourg remains in an intermediate position. Italy, Greece, Spain and

[4] Unit root tests, not reported here to save space, accept the hypothesis of stationarity for the first diferences of all the series.

Portugal seem to form another group as well.

The first row of Table 4.2 displays the correlation coefficient of each country with a composite variable called EU, constructed as a weighted average of the values of each country, using as weights the share in EU GNP of each country. This composite variable is significantly correlated with consumption in Belgium, Netherlands, Italy, Greece and Spain. However, we have to be careful in interpreting these results, since the composite variable is an average of the 12 countries of the EU. That means that the bigger countries are more likely to present higher correlations, and the countries with significant more variability will contribute decisively to the variability of the composite variable, and that will be also reflected in the correlations. This can be the case, for example, of Italy, which shows a standard deviation of 0.083 whereas the rest of the countries show values around 0.02-0.03. This may imply that significant correlations with the EU may only be really significant for our interpretation in the cases of Belgium and Netherlands, and perhaps in the case of Greece, since Italy and Spain are relatively large countries which display a high degree of variability. In order to check this fact, the second row of Table 4.2 presents the correlation coefficients of each country's consumption with a variable called 'rest of the EU', that contains for each country the EU less the country itself. As we can see, the coefficients are lower for the big countries, although Italy and Greece still present significant coefficients.

### Regression analysis

Recalling the theoretical implications of the international risk sharing proposition, we will estimate eq.(4.15). The aggregate consumption variable will be the composite variable representing the rest of the EU for each country. The other right hand side variables will be: U.S. consumption, U.S. GNP, U.S. short term interest rates and oil prices as common external variables. For each country we will also consider population, rate of inflation, personal income (proxied by GNP per capita) and government consumption. Therefore, we will estimate for each country eight regressions, one for each right hand side variable, and we will test two hypotheses:

$H_0 : \beta_1 = 0$ so no risk sharing occurs

$H_0 : \beta_1 = 1$ and $\beta_2 = 0$, so that markets are completely integrated

But we have n observations over time in m equations for different cross section units. This implies that the residuals of this equations may be contemporaneously correlated across units. Therefore, using a SURE procedure seems the most adequate approach to use. The results appear in tables 4.3 and 4.4.

Regarding the case of common external variables, the hypothesis of $\beta_1 = 0$ is only accepted for Denmark, Germany and Italy. Conversely, the hypothesis of $\beta_1 = 1$ is only accepted for Italy, Greece, Netherlands, Portugal and Spain. For the external variables, $\beta_2 = 0$ is only rejected for two countries, Denmark and U.K. Finally, the joint hypothesis is tested with an F-test. Ireland, Italy, Greece, Netherlands, Portugal and Spain are the only countries that accept the hypothesis of perfect risk sharing. But the interpretation of these results should be done carefully. Italy is by far the country with more variability in the series. That has the implication of higher standard errors and hence $\beta_1$ is accepted to be not significantly different from either 0 or 1. Greece, Portugal and Spain have been traditionally countries with quite closed markets, and therefore it seems strange that these are the countries with more integrated markets. One explanation could be that the hypothesis of risk sharing could be accepted in the extreme case of autarky. Given that consumption depends on income, if two autarkic countries suffer from a common shock to income their consumption streams will move relatively together even if the markets are closed. In that case, we could distinguish autarky form risk sharing checking the relationship of national consumption with national income. If the latter is strong, the previous results could indicate a high degree of closeness of the economies. Finally, The Netherlands and Ireland seem to be the only countries with a high degree of risk sharing with respect to common external variables. The Irish case could also be tricky, since Ireland is a country that trades mainly with the U.K.. The U.K. is a big country and has an important weight in the composite variable used in the regressions of Ireland. Therefore, it may be the case that Ireland is not sharing its risks within the EU but just with the U.K.. Denmark and Germany are the countries that seem not to share any risk at all within the EU. This is not necessarily a sign of closeness of the markets, it may imply the existence of trade relationships outside the EU, with Nordic or Eastern European countries, for example.

Regarding idiosyncratic variables, again Denmark and Germany are the only countries that accept the hypothesis $\beta_1 = 0$. Population enters significantly for Belgium. Portugal and France, inflation and government spending enter significantly in the equations of some countries but by far the most important variable across countries is personal income, being insignificant only for Denmark, Germany and the U.K. The F-test (tables 4.5 and 4.6) shows similar results as before regarding the countries: France, Italy, Greece, Netherlands, Portugal, Spain and U.K. are the countries that accept the hypothesis of perfect risk sharing for some of the variables. Population, inflation and government spending seem to be well insured, but personal income is only insured by Netherlands. Hence, our previous hypothesis seems to be correct, since Greece, Portugal and Spain depend significantly on national income, confirming the intuition of closeness instead of openness. Italy, France, Netherlands and U.K. are the only countries that have shared idiosyncratic risks to some extent within the EU. Belgium, Ireland and Luxembourg show some risk sharing but not perfect and Germany and Denmark look to be the countries that are more independent of the EU.

If we estimate both systems under the restriction of equality of coefficients, we obtain the following parameter estimates of $\beta_1$

| *USC* | *USG* | *USi* | *OilP* | *POP* | *INF* | *INC* | *GOV* |
|---|---|---|---|---|---|---|---|
| 0.61 | 0.60 | 0.62 | 0.64 | 0.54 | 0.25 | 0.23 | 0.37 |
| (0.06) | (0.07) | (0.06) | (0.02) | (0.04) | (0.09) | (0.08) | (0.10) |

These parameters may be interpreted as the 'average risk sharing' across Europe with respect to each of the variables. The average of these parameters, 0.48, could then be interpreted as the average fraction of risk that the members of the EU are pooling inside the EU.

**Temporal evolution**

All empirical studies dealing with risk sharing have found an increase in the degree of market integration from 1973 onwards (see Obstfeld(1993), for example). This fact has been checked by computing the previous correlations coefficients for the subsample 1973-1990. The third row of Table 4.2 shows the values of the correlation coefficient of each country's consumption with the composite variable for the subsample 1973 - 1990, and we can see that now all the coefficients are significant, whereas for the whole sample only five countries were significantly correlated with the composite.

In order to determine the evolution of that increase in the correlations we have computed recursive correlation coefficients of each country consumption with the aggregate, starting in 1972. Figure 4.1 displays the time value of these coefficients for the period 1972-1990. The main conclusions that can be drawn from this picture are that there is a break in the behavior of the majority of the countries around 1972-76, a break that probably reflects the different impact of the oil crises in the different European countries. After this break, around 1980, the coefficients stabilize being more or less grouped at the end of the period.

A further confirmation of the latter fact is to check the variability of the series in the two subsamples. If risk sharing occurs more integrated markets should display less variability. The following table shows the percentage standard deviations of the series for the two subsamples, and in all the cases except for Denmark, Ireland and Portugal the distance test reveals that the coefficient has decreased [5]

| | *B* | *D* | *F* | *G* | *IR* | *IT* | *GR* | *LU* | *NE* | *PT* | *SP* | *UK* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *S.D.* | 1.8 | 3.7 | 2.4 | 2.5 | 3.7 | 8.3 | 3.3 | 2.8 | 3.1 | 4.1 | 4.4 | 3.0 |
| *s.e.* | (0.1) | (0.2) | (0.1) | (0.1) | (0.2) | (0.5) | (0.2) | (0.2) | (0.3) | (0.3) | (0.3) | (0.2) |
| *S.D.* | 1.5 | 3.5 | 2.1 | 2.0 | 3.5 | 3.6 | 2.9 | 2.3 | 2.2 | 4.4 | 3.0 | 2.0 |
| *s.e.* | (0.1) | (0.2) | (0.1) | (0.1) | (0.2) | (0.2) | (0.1) | (0.1) | (0.1) | (0.3) | (0.3) | (0.1) |
| *d.t.* | 3.90 | 0.51 | 4.51 | 12.5 | 0.54 | 24.5 | 2.01 | 2.04 | 8.12 | 0.05 | 10.88 | 5.55 |

Finally, if we now repeat the regression for the subsample 1973-1990, the F-test is accepted for many more countries (see tables 4.5 and 4.6). With respect to external variables, Germany in now the only country rejecting in all the cases the risk sharing hypothesis and countries like France or Belgium that rejected before now accept in all the cases. The same happens with respect to the idiosyncratic variables, and now even Germany accepts the risk sharing proposition for population and government spending. Hence, it seems that both the general opening of the markets and the process of integration in Europe has contributed to some extent to the pooling of consumption risks in the EU. However, we still find some differences across countries.

[5] The first row are the values for the whole period 1960-1990. The second are the values for the subsample 1973-1990). The third row are the values of a distance test. The critical value for the hypothesis of equality of coefficients at 95 % is a $\chi(1)$ :3.78

**VAR analysis**

We have stated before that under full consumption risk sharing the response to common external shocks should be the same across countries and the magnitude of the response broadly similar among the group of countries. If a country is hit by a common shock but not another we have a clear example of a situation in which risk has not been pooled. Thus, we could summarize the intuition that lies behind the risk sharing proposition as no response to idiosyncratic shocks and similar responses to common shocks. This intuition is in some sense dynamic, since we are talking of shocks today and its effect in the future, and therefore it seems that the traditional static regression analysis may not be enough to fully test the risk sharing conditions of a group of countries. Furthermore, as we have seen in the theoretical discussion, risk sharing tests based on static regressions may be flawed by the possibility of heterogeneous countries with diferences in the degree of risk aversion. Our test may be weaker but more intuitive, and overcomes this difficulties. Hence, we will introduce these dynamics through the study of the responses of consumption in each country to common and idiosyncratic shocks.

The shocks are computed as the first differences of the series. The external shocks that we have selected are: U.S. consumption (USC), U.S. GNP (USGNP), U.S. interest rate (USi) and oil prices (Op). We have selected the U.S. because of its importance in the world economy. U.S. consumption will allow us to determine the degree of risk sharing and hence of capital mobility between Europe and the U.S. Interest rates and GNP are selected in order to introduce the effects of U.S. economic policies. Oil prices are included because the European economies are still in general highly dependent on oil imports.

With a similar criteria, we have selected idiosyncratic shocks so as to cover different sources of shocks that may occur in the real economies: national population (Pop), inflation rate (Π), government spending (G) and GNP per capita (GNPP). A better variable to be used for the fiscal shock would have been government deficit, but we could not find sufficient good data to construct it. Even the government spending series were not available for Luxembourg.

With these set of variables we will specify two VARs for each country each containing national consumption (NC) and one of the vectors of shocks, $S_t^c$ with the common shocks and $S_t^i$ with the idiosyncratic shocks. Therefore, we will estimate for each country and each vector of shocks

$$X_{t+1}^j = B(L)X_t^j + \epsilon_{t+1}^j \tag{4.16}$$

where $X_t^j = [\Delta \log C_t^j, S_t]$ and we will set L=2 according with the Hannan and Quinn criterium.

The Wold ordering of the variables is [Op USi USC USGNP NC] and [Pop G Π GNPP NC]. Given that the modelling of individual economies is beyond the scope of this paper but taking into account that the Wold ordering affect the the results, we have checked the covariance matrix of the residuals of each VAR and perform some sensitivity analysis in order to check the robustness of our results to the ordering. In an appendix it is shown that the off diagonal elements of the covariance matrices of the residuals are close to zero in almost all the cases and that the results obtained with different orderings are not qualitatively different from the ones presented here.

We will compute the orthogonal impulse response functions and check the following conditions: with respect to the common shocks, we will compute the response of the aggregate and then compare the responses of each country with the rest of the countries and with the aggregate, since we are expecting common responses to common shocks. With respect to idiosyncratic shocks, we will check whether the responses of each country are significantly different from zero, since we are expecting no response to idiosyncratic shocks. In order to be able to say that a response is different from another one we need the standard errors of this impulse response, that are computed with the method of Lütkepohl (1991).

In order to have some quantitative evidence on the level of risk sharing and on the importance of each of the shocks, we will also compute the variance decomposition. This informs us on the percentage of variance of the forecast error of a given variable that is due to each of the other variables. The percentage of the variance that is not explained by the shocks could be interpreted as the 'degree of risk sharing' of each country in this dynamic framework.

However, we should be cautious with this interpretation. The ideal specification of this test would have been to construct only one VAR with all the possibles sources of shocks included. But in that case we would have encountered the problem of lack degrees of freedom and of the modelling of causallity is such a large VAR. But having specified two different VARs for each country it is possible that the residual unexplained forecast error variance that is not explained by one set of shocks is explained by the other set of shocks, in which case the interpretation of this value as the amount of risk sharing would be misleading. In order to control for this fact we have conducted the following test. We have for each country two VARs:

$$X^j_{t+1} = B(L)X^j_t + \epsilon^j_{t+1} \tag{4.17}$$

and

$$Y^j_{t+1} = D(L)Y^j_t + \gamma^j_{t+1} \tag{4.18}$$

where $X_t = [C^j_t S^c_t]$ and $Y_t = [C^j_t S^i_t]$. Now we can compute the following regressions:

$$\epsilon_{t+1} = B_1(L)Y_t + v_t \tag{4.19}$$

and

$$\gamma_{t+1} = D_1(L)X_t + u_t \tag{4.20}$$

and test the hypothesis $H_0 : B_1(L) = 0$ and $D_1(L) = 0$. If we accept the null hypothesis then our interpretation is correct provided that our model is well specified and that there are not measurement errors. Otherwise we should use the *purged* variables $u_t$ and $v_t$ as the dependent variables. The results of this test appear in the following panel (F-test C.V.:1.80). We can see that in all the cases we accept the null hypothesis and therefore we can acept our interpretation as valid.

| | $B$ | $D$ | $F$ | $G$ | $IR$ | $IT$ | $GR$ | $LU$ | $NE$ | $PT$ | $SP$ | $UK$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Eq.4.19$ | 0.88 | 1.20 | 1.36 | 0.87 | 1.25 | 0.74 | 0.56 | 1.03 | 1.30 | 1.06 | 1.20 | 1.05 |
| $Eq.4.20$ | 0.69 | 0.58 | 0.99 | 1.58 | 1.23 | 0.96 | 0.69 | 1.11 | 0.88 | 1.02 | 1.70 | 1.09 |

**Common external shocks** Figures 4.2, 4.3, 4.4 and 4.5 show the orthogonalized responses over ten periods of each of the countries and the composite variable EU to the external shocks, and our goal will be double: we have two conditions, the first one that the responses of any pair of countries will be equal and the second, less strong due to the averaging procedure, that the response of each country will be equal to the response of the composite variable.

The following panel summarizes the information contained in Figs. 4.2, 4.3, 4.4 and 4.5 by analysing whether the individual responses are similar on the basis of its statistical significance/non significance and, when significant, on the sign and period (i.e. +3 means that the impulse response is significantly different from zero three periods ahead). In order to compare the responses of each of the countries with those of the aggregate, Figs. 4.6, 4.7, 4.8 and 4.9 show the two standard error bands for the impulse response of each country together with that of the EU to each of the shocks. In the case that the bands show no point in common at some time, we could establish that the responses are different at that time. These cases are indicated in the panel with a *.

| | *eu* | *b* | *d* | *f* | *g* | *ir* | *it* | *gr* | *lu* | *ne* | *pt* | *sp* | *uk* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *usc* | | −3 | +2 − 3 | | | +2 | +2 | | | +2 | | | +2 |
| *usg* | | −2 | | | −2 | | +2 | | −2 | | | | −2 |
| *usi* | +4 | −1 | | −2 + 3 | | +4 | +4 | −2 | | | | −2 | |
| *op* | −3 | | +2* | | | | +2 | +2* | −3 | | | −2 | |

To U.S. consumption we find negative responses in the third period for Belgium and Denmark and positive responses in the second period for Denmark, Netherlands, Italy, Ireland and the U.K. To U.S. GNP Belgium, Germany, Luxembourg and the U.K. react negatively also in the second period while Italy reacts positively. Belgium, France, Greece and Spain display negative responses while EU, France, Ireland and Italy show positive responses to U.S. interest rates. Finally, EU, Denmark, Italy, Greece, Luxembourg and Spain have significant responses to oil prices. Regarding the comparison of responses with the aggregate, the result is that only Denmark and Greece present this divergence, in the case of the impulse response to the oil price shock.

Table 4.7 presents the variance decomposition of consumption in each country after five periods. We can see that the percentage of variance not due to external shocks is similar across countries, around 60 %, while Portugal and France are the less affected countries, with 83 % and 78 % respectively. The most important shocks are U.S. interest rates and oil prices, which account for a 13 % and a 16% of the variance of european consumption respectively.

**Idiosyncratic shocks** The first implication of the risk sharing proposition was that the response to a external shock should be equalized across countries. The second implication is that the response of each country to idiosyncratic shocks should be zero once we have taken into account the effect of this shock on the aggregate. Intuitively this occurs because if a country has diversified its risk it is hedged against any idiosyncratic shock not suffered by the group with which the pooling of risks occurs. Hence, we test this second implication of the theory by studying the response of each country to national shocks .

The impulse responses (Figs. 4.9, 4.10 and 4.11) are again summarized in the following panel

| | *eu* | *b* | *d* | *f* | *g* | *ir* | *it* | *gr* | *lu* | *ne* | *pt* | *sp* | *uk* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *pop* | | | | | | +3∗ | | | | | +3∗ | | |
| inf | | | +2∗ | −2∗ | | | | +2 | | −2 | | | +2 |
| *inc* | | | | −3 | | −2 | −3 | −2∗ | | | | | |
| *gov* | | | | +2 | | +2 − 3 | +3 | +2 | | | | | |

We can see that population shocks generate responses significantly different from zero in consumption for Ireland and Portugal, positive in the third period. Inflation shocks generate significant consumption responses for Denmark, Greece and U.K. (positive in the second period) and France and Netherlands (negative in the second). Personal income shocks affect per capita consumption in Ireland and Greece in the second period and France and Italy in the third. Government spending affects also France, Ireland, Italy and Greece. Therefore we find that countries with different structures react differently and in different periods, but significant responses are concentrated in the so-called 'peripheral' countries. The comparison of each country's 2 s.e. band with that of the EU (Figs. 4.12, 4.13 and 4.14) says that Denmark, France, Ireland, Greece and Portugal are the countries that present responses different from the aggregate one.

The variance decomposition analysis (table 4.7) shows that after 5 years around a 70 % of the variance is not explained by idiosyncratic shocks. Greece, Ireland and Portugal show the lowest values while Germany, Luxembourg and Spain show values greater than 80 %. The most important shock in this case is government spending, which accounts for a 13% of the variance of european consumption. Interestingly, no country presents a response to government spending different from that of the aggregate, even though there are countries with significant responses to this shock. This means that although non significant in statistical terms, the response of the EU to government spending shocks is qualitatively important, reflecting the fact that the public sector has still a large weight in Europe.

Putting together the results obtained with both systems we can obtain a better picture of the situation and clarify the grouping of countries. With this aim Figure 4.15 presents the cross-plot of the amount of variance that is not explained by both types of shocks. It shows a group of countries that behave quite similarly and that would form the 'core' of the Union whereas the 'periphery' would include Spain, Portugal, Ireland, France, Denmark and Italy.

In summary, we can state that after five years around a 60 % of the common shocks and a 70 % of the idiosyncratic shocks that affect the European economies are shared within the EU. It may be interesting to compare these results with the previous static analysis. In that case, the amount of risk shared inside the Union is around 60% of the common external shocks and 30% of the idiosyncratic shocks. We can see that the percentage of idiosyncratic shocks shared has increased with the increase in the time dimension of the analysis, but not the percentage of common shocks, a fact that could indicate the rigidities that characterize the european economies.

**Granger-causality** As we have stated before, incorporating the lag structure of the VARs allows us to test whether past and present values of the external variables help in predicting the behaviour of consumption series and hence allow for countries that react systematically with some lag. As should be clear, we expect that no idiosyncratic variable should help in predicting domestic consumption and that external variables should help only to the extent that they help to predict aggregate consumption. In table 4.8 we present the results of Granger causality tests both on individual variables and on the block of exogenous variables.

Regarding external shocks, all the countries except France and Portugal reject the block-noncausality hypothesis. In the case of idiosyncratic shocks, France, Ireland and Greece seem to be the most affected whereas Luxembourg, Netherlands, Italy, Germany and Belgium are the countries that pass the test of block noncausality.

Given that this is the dynamic equivalent to an F-test in static regression analysis, we can compare again these results with those obtained in the previous part. With static regressions Ireland, Italy, Greece, Netherlands, Portugal and Spain accept the hypothesis of perfect risk sharing. Greece, Portugal and Spain have been traditionally countries with quite closed markets, and therefore it seems strange that these are the countries with more integrated markets.

The explanation is that the hypothesis of risk sharing could be accepted in the extreme case of autarky. Given that consumption depends on income, if two autarkic countries suffer from a common shock to income their consumption streams will move relatively together even if markets are closed. In this case, we could distinguish autarky form risk sharing checking the relationship of national consumption with national income. If the latter is strong, the previous results could indicate a high degree of closeness of the economies. In fact the hypothesis seems to be correct, since Greece, Portugal and Spain depend significantly on national income, confirming the intuition of closeness instead of openness.

However, Granger-causality tests in the VARs present somehow different results. Spain and Greece reject noncausality for all the variables, and it seems that this is a way to overcome somehow the difficulty of distinguishing between perfect risk sharing and autarky. Relatively closed countries will react to common external shocks with some lags, and hence the static regression analysis will clearly fail to reflect this feature. Portugal is still showing noncausality to external variables but, given that even incorporating the lag structure it still react to idiosyncratic variables (see the second panel of table 4.8), we may conclude that Portugal is the most closed country of the panel under study.

The cross-plot (Figure 4.16) shows a pattern of aggrupation similar to one obtained with the variance decomposition, with Spain, Portugal, Ireland, France, Denmark and Italy out of the 'core' of the Union.

## 4.5 Conclusion

Concluding, we have seen that, in a world of representative agents with open markets, international consumption risk sharing would be one of the main characteristics even without complete capital markets. Our empirical investigation has analyzed the dynamic implications of the theory with respect to a wide range of possible shocks that may affect the economies.

We can summarize our empirical results in the following points. First, we have found some evidence of risk sharing among European countries, since a fraction of the risks of around 60-70% within five years is shared inside the EU.

Secondly, we can make a distintion between the 'core' and the 'periphery', a fact that may indicate that in terms of optimal currency areas the EU may not be ready yet. The 'core' would be composed by the Benelux plus Germany and the U.K. Then, France, Ireland, Portugal, Spain, Greece and Italy would form the 'periphery', a fact that is not too surprising given the historical and economic characteristics of these countries. Traditionally Portugal, Greece and Spain have had an autarkic behaviour and Ireland is perhaps more linked with U.K. than with Europe. Denmark is an special case, because being an open country it does not show a high relationship with Europe, being perhaps the reason its close links with the Scandinavian countries. Finally, Italy should belong to the 'core' according to its historical tradition, but the huge volatility of its macrovariables relegates her to the periphery. It is interesting to see that these are the countries that have suffered the most in the recent ERM crisis.

These differences among countries are not only due to market imperfections but also to the structural particularities of the different economies. They may also be related to national institutions and policy variables, and common institutions and policies should be directed to the narrowing of these gaps. For example, the fact that the older members of the EU are the countries inside the 'core' may indicate that the European unification process has contributed to a better diversification of risks.

Third, the exogenous variables that have the greatest influence on the cyclical properties of the countries are US interest rates, oil prices and government spending. The oil price is not a surprising result given the strong general dependence of the economies on oil products. U.S. interest rates reveal the fact that during these years the U.S. has dominated capital markets and in some sense determined some economic policy decisions in European countries. We suspect that from the 80's onwards this role has been played in Europe by Germany and that in order to repeat this analysis for the last 10 years it would be more correct to use German interest rates. Finally, the fact that government spending has an importance in explaining european cyclical fluctuations can be explained by the dimension of public sectors in the european economies and the proliferation of public insurance schemes. The results here obtained could serve as a guide for reformulating public policies that should try to minimize the effect of this variables.

Our results are consistent with those of Canova and Ravn (1993), Obstfeld (1993) and Lewis(1993) in that they find substantial degrees of risk sharing in OECD countries. We are also in the line of real business cycle theorists since we have found that risk sharing can be imperfect even in a world with integrated capital markets (see, e.g. Canova and Ubide (1995)) and that government expenditure has a significant effect over the business cycle (Christiano and Eichenbaum (1992)).

Finally, regarding the design of insitutions the results of this Chapter suggest the necessity of new institutions intended to increase the efficiency of the markets and to help the nations with structural problems (see, e.g., Persson and Tabellini (1992)). However, regarding the short term, the stabilizing role that should be played by exchange rates could perfectly be played by wider and more automatic borrowing facilities for the governments that may need some help in case of a particular hard shock, and no specific insurance scheme seems to be needed.

Table 4.1: Correlation matrix of consumption series 1960-1990

| | D | F | G | IR | IT | GR | LU | NE | PT | SP | UK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B | 0.18 | 0.50 | 0.34 | 0.59 | 0.33 | 0.49 | 0.27 | 0.47 | 0.49 | 0.32 | 0.25 |
| | (0.11) | (0.13) | (0.14) | (0.07) | (0.22) | (0.15) | (0.09) | (0.16) | (0.17) | (0.23) | (0.09) |
| D | | 0.25 | 0.25 | 0.13 | -0.12 | 0.29 | 0.13 | 0.34 | -0.29 | 0.01 | 0.23 |
| | | (0.12) | (0.10) | (0.12) | (0.13) | (0.14) | (0.07) | (0.14) | (0.12) | (0.13) | (0.10) |
| F | | | 0.24 | 0.37 | 0.24 | 0.41 | 0.16 | 0.18 | 0.28 | 0.13 | 0.29 |
| | | | (0.16) | (0.10) | (0.20) | (0.13) | (0.06) | (0.21) | (0.16) | (0.24) | (0.10) |
| G | | | | 0.42 | 0.10 | 0.36 | 0.45 | 0.69 | -0.04 | -0.04 | 0.07 |
| | | | | (0.09) | (0.19) | (0.12) | (0.07) | (0.10) | (0.19) | (0.23) | (0.09) |
| IR | | | | | 0.18 | 0.30 | 0.11 | 0.45 | 0.21 | 0.28 | 0.29 |
| | | | | | (0.14) | (0.11) | (0.06) | (0.09) | (0.16) | (0.12) | (0.08) |
| IT | | | | | | 0.55 | 0.06 | 0.45 | 0.34 | 0.50 | 0.14 |
| | | | | | | (0.20) | (0.06) | (0.22) | (0.17) | (0.12) | (0.08) |
| GR | | | | | | | 0.01 | 0.61 | 0.01 | 0.46 | 0.14 |
| | | | | | | | (0.06) | (0.14) | (0.18) | (0.13) | (0.09) |
| LU | | | | | | | | 0.31 | 0.15 | 0.19 | 0.11 |
| | | | | | | | | (0.11) | (0.05) | (0.07) | (0.06) |
| NE | | | | | | | | | -0.02 | 0.30 | 0.17 |
| | | | | | | | | | (0.18) | (0.22) | (0.09) |
| PT | | | | | | | | | | 0.13 | 0.06 |
| | | | | | | | | | | (0.15) | (0.09) |
| SP | | | | | | | | | | | 0.28 |
| | | | | | | | | | | | (0.08) |

Table 4.2: Correlation matrix of consumption series with the aggregate EU

| B | D | F | G | IR | IT | GR | LU | NE | PT | SP | UK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.51 | 0.11 | 0.51 | 0.37 | 0.45 | 0.85 | 0.68 | 0.24 | 0.64 | 0.34 | 0.62 | 0.44 |
| (0.30) | (0.46) | (0.36) | (0.40) | (0.42) | (0.11) | (0.17) | (0.45) | (0.23) | (0.43) | (0.28) | (0.44) |
| 0.55 | 0.09 | 0.37 | 0.18 | 0.43 | 0.45 | 0.66 | 0.24 | 0.60 | 0.29 | 0.48 | 0.25 |
| (0.25) | (0.33) | (0.28) | (0.30) | (0.29) | (0.25) | (0.16) | (0.32) | (0.20) | (0.30) | (0.25) | (0.33) |
| 0.74 | 0.37 | 0.63 | 0.33 | 0.60 | 0.79 | 0.38 | 0.40 | 0.68 | 0.34 | 0.72 | 0.66 |
| (0.07) | (0.11) | (0.06) | (0.08) | (0.06) | (0.12) | (0.09) | (0.07) | (0.13) | (0.12) | (0.16) | (0.14) |

Note:the first row corresponds to the correlations with the EU for the whole sample 1960-1990. The second row to the correlations with the 'rest of the EU' for the whole sample. The third to the correlations with the EU for the subsample 1973-1990. Standard errors in brackets.

Table 4.3: Regression results

| Country | USC | | USG | | USi | | OILP | |
|---|---|---|---|---|---|---|---|---|
| | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ |
| B | 0.41 | 0.05 | 0.44 | -0.02 | 0.90 | -0.24 | 0.89 | -0.14 |
| | (0.13) | (0.12) | (0.14) | (0.10) | (0.07) | (0.05) | (0.08) | (0.04) |
| | 3.08 | 0.37 | 3.10 | -0.17 | 13.85 | -5.29 | 11.39 | -3.58 |
| | -4.43 | -7.78 | -4.01 | -9.95 | -1.52 | -27.42 | -1.45 | -28.31 |
| D | -0.04 | 0.47 | -0.02 | 0.24 | 0.33 | 0.86 | 0.41 | 0.44 |
| | (0.15) | (0.14) | (0.18) | (0.13) | (0.28) | (0.20) | (0.22) | (0.12) |
| | -0.25 | 3.34 | -0.13 | 1.79 | 1.17 | 4.31 | 1.85 | 3.80 |
| | -6.85 | -3.76 | -5.68 | -5.75 | -2.37 | -0.72 | -2.65 | -4.77 |
| F | 0.33 | 0.18 | 0.36 | 0.05 | 0.70 | -0.05 | 0.66 | 0.01 |
| | (0.17) | (0.15) | (0.18) | (0.13) | (0.20) | (0.12) | (0.21) | (0.10) |
| | 1.91 | 1.22 | 1.96 | 0.37 | 3.53 | -0.41 | 3.15 | 0.14 |
| | -3.88 | -5.46 | -3.47 | -7.57 | -1.54 | -8.46 | -1.63 | -10.03 |
| G | 0.13 | 0.23 | 0.15 | 0.08 | 0.06 | 0.24 | 0.04 | 0.19 |
| | (0.19) | (0.16) | (0.20) | (0.14) | (0.10) | (0.07) | (0.07) | (0.03) |
| | 0.71 | 1.40 | 0.76 | 0.55 | 0.57 | 3.54 | 0.63 | 5.59 |
| | -4.69 | -4.74 | -4.17 | -6.58 | -9.33 | -11.10 | -14.28 | -23.93 |
| IT | 0.59 | 0.22 | 0.45 | 0.35 | 1.29 | 0.19 | 1.07 | 0.48 |
| | (0.18) | (0.16) | (0.18) | (0.13) | (0.17) | (0.12) | (0.21) | (0.11) |
| | 3.32 | 1.34 | 2.43 | 2.63 | 7.56 | 1.58 | 5.04 | 4.30 |
| | -2.31 | -4.73 | -2.99 | -4.79 | 1.71 | -6.76 | 0.34 | -4.68 |
| IR | 2.67 | -0.02 | 2.19 | 0.45 | 2.00 | -0.49 | 1.96 | -0.31 |
| | (2.06) | (1.10) | (2.04) | (0.86) | (0.62) | (0.33) | (0.71) | (0.28) |
| | 1.30 | -0.02 | 1.08 | 0.52 | 3.21 | -1.48 | 2.77 | -1.13 |
| | 0.81 | -0.92 | 0.59 | -0.64 | 1.60 | -4.50 | 1.36 | -4.71 |
| GR | 0.86 | 0.19 | 0.82 | 0.18 | 0.37 | 0.47 | 0.36 | 0.34 |
| | (0.19) | (0.17) | (0.20) | (0.15) | (0.23) | (0.16) | (0.20) | (0.10) |
| | 4.49 | 1.11 | 4.03 | 1.23 | 1.65 | 2.95 | 1.79 | 3.22 |
| | -0.71 | -4.63 | -0.89 | -5.65 | -2.79 | -3.39 | -3.21 | -6.35 |
| LU | 0.31 | -0.07 | 0.33 | -0.07 | 0.72 | -0.07 | 0.72 | -0.05 |
| | (0.13) | (0.12) | (0.14) | (0.10) | (0.13) | (0.09) | (0.12) | (0.07) |
| | 2.38 | -0.58 | 2.41 | -0.68 | 5.58 | -0.81 | 5.78 | -0.69 |
| | -5.17 | -8.67 | -4.85 | -10.54 | -2.18 | -11.71 | -2.30 | -15.90 |
| NE | 0.79 | 0.03 | 0.81 | -0.01 | 0.75 | 0.26 | 0.75 | 0.17 |
| | (0.22) | (0.20) | (0.23) | (0.17) | (0.29) | (0.20) | (0.28) | (0.14) |
| | 3.56 | 0.17 | 3.44 | -0.07 | 2.54 | 1.26 | 2.70 | 1.24 |
| | -0.96 | -4.85 | -0.83 | -6.07 | -0.86 | -3.69 | -0.92 | -5.84 |
| PT | 0.54 | -0.11 | 0.63 | -0.20 | 1.09 | -0.78 | 1.00 | -0.43 |
| | (0.29) | (0.27) | (0.31) | (0.22) | (0.72) | (0.50) | (0.68) | (0.35) |
| | 1.88 | -0.43 | 2.05 | -0.91 | 1.52 | -1.57 | 1.49 | -1.22 |
| | -1.59 | -4.20 | -1.20 | -5.40 | 0.12 | -3.58 | 0.01 | -4.07 |
| SP | 1.12 | -0.33 | 0.88 | 0.15 | 1.14 | 0.09 | 1.16 | 0.03 |
| | (0.22) | (0.18) | (0.23) | (0.15) | (0.43) | (0.26) | (0.43) | (0.20) |
| | 5.04 | -1.80 | 3.83 | 0.99 | 2.68 | 0.36 | 2.69 | 0.17 |
| | 0.54 | -7.23 | -0.53 | -5.69 | 0.34 | -3.44 | 0.38 | -4.85 |
| UK | 0.23 | 0.31 | 0.19 | 0.22 | 0.79 | 0.41 | 0.79 | 0.24 |
| | (0.12) | (0.10) | (0.13) | (0.09) | (0.28) | (0.16) | (0.34) | (0.15) |
| | 1.93 | 2.98 | 1.44 | 2.47 | 2.78 | 2.47 | 2.34 | 1.64 |
| | -6.34 | -6.62 | -6.02 | -8.52 | -0.74 | -3.60 | -0.61 | -5.17 |

Note: For each country, the first row is the parameter estimate, the second is the standard error, the third the t-statistic for the hypothesis $\beta = 0$ and the fourth for the hypothesis $\beta = 1$

Table 4.4: Regression results

| Country | POP | | INF | | INC | | GOV | |
|---|---|---|---|---|---|---|---|---|
| | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ |
| B | 0.71 | -2.70 | 0.42 | -0.15 | 0.29 | 0.30 | 0.37 | 0.16 |
| | (0.16) | (1.35) | (0.14) | (0.12) | (0.09) | (0.06) | (0.11) | (0.06) |
| | 4.38 | -2.00 | 2.90 | -1.25 | 3.25 | 4.64 | 3.38 | 2.67 |
| | -1.75 | -2.74 | -4.05 | -9.58 | -8.06 | -11.08 | -5.74 | -13.63 |
| D | 0.61 | -4.72 | 0.16 | -0.04 | -0.17 | 0.68 | 0.45 | -0.26 |
| | (0.35) | (2.52) | (0.16) | (0.13) | (0.11) | (0.09) | (0.26) | (0.14) |
| | 1.75 | -1.87 | 0.98 | -0.34 | -1.54 | 7.60 | 1.71 | -1.89 |
| | -1.11 | -2.27 | -5.30 | -8.04 | -10.50 | -3.50 | -2.11 | -9.14 |
| F | 0.31 | 3.96 | 0.48 | -0.10 | 0.25 | 0.41 | 0.56 | -0.06 |
| | (0.09) | (0.89) | (0.17) | (0.11) | (0.08) | (0.06) | (0.16) | (0.08) |
| | 3.53 | 4.44 | 2.82 | -0.95 | 3.31 | 7.42 | 3.42 | -0.74 |
| | -7.68 | 3.32 | -3.10 | -10.39 | -9.92 | -10.61 | -2.65 | -13.20 |
| G | 0.43 | -0.95 | 0.25 | -0.36 | 0.02 | 0.41 | 0.19 | 0.16 |
| | (0.24) | (1.06) | (0.23) | (0.26) | (0.15) | (0.10) | (0.13) | (0.07) |
| | 1.79 | -0.89 | 1.09 | -1.35 | 0.11 | 4.23 | 1.50 | 2.34 |
| | -2.41 | -1.84 | -3.28 | -5.15 | -6.45 | -5.98 | -6.32 | -12.52 |
| IR | 2.88 | 0.90 | 3.26 | 0.27 | 2.86 | -0.11 | 2.91 | -0.15 |
| | (0.31) | (1.11) | (0.43) | (0.19) | (0.30) | (0.16) | (0.34) | (0.12) |
| | 9.33 | 0.81 | 7.58 | 1.42 | 9.63 | -0.69 | 8.46 | -1.25 |
| | 6.10 | -0.09 | 5.26 | -3.93 | 6.26 | -6.91 | 5.55 | -9.49 |
| IT | 1.67 | -1.12 | 1.25 | -0.16 | 1.37 | 0.09 | 1.43 | 0.08 |
| | (0.21) | (1.37) | (0.35) | (0.10) | (0.34) | (0.09) | (0.34) | (0.07) |
| | 7.84 | -0.81 | 3.59 | -1.66 | 4.05 | 1.03 | 4.20 | 1.19 |
| | 3.15 | -1.54 | 0.73 | -12.13 | 1.10 | -10.30 | 1.26 | -13.89 |
| GR | 0.88 | -0.50 | 0.34 | -0.23 | 0.64 | 0.17 | 0.85 | 0.08 |
| | (0.20) | (1.06) | (0.14) | (0.04) | (0.18) | (0.07) | (0.16) | (0.07) |
| | 4.46 | -0.47 | 2.50 | -5.27 | 3.57 | 2.58 | 5.24 | 1.17 |
| | -0.59 | -1.42 | -4.87 | -28.42 | -2.04 | -12.25 | -0.92 | -13.24 |
| LU | 0.25 | 0.31 | 0.15 | -0.20 | 0.33 | -0.11 | 0.00 | 0.00 |
| | (0.13) | (0.26) | (0.12) | (0.10) | (0.14) | (0.05) | 0.00 | 0.00 |
| | 1.90 | 1.20 | 1.24 | -1.96 | 2.37 | -1.96 | 0.00 | 0.00 |
| | -5.62 | -2.65 | -7.01 | -11.65 | -4.91 | -20.32 | 0.00 | 0.00 |
| NE | 0.84 | -0.34 | 0.82 | 0.16 | 0.45 | 0.45 | 0.52 | 0.30 |
| | (0.31) | (2.29) | (0.17) | (0.14) | (0.20) | (0.15) | (0.14) | (0.08) |
| | 2.72 | -0.15 | 4.85 | 1.11 | 2.20 | 2.97 | 3.77 | 3.90 |
| | -0.51 | -0.58 | -1.08 | -6.03 | -2.74 | -3.64 | -3.51 | -9.09 |
| PT | 0.70 | -0.86 | 0.10 | -0.29 | 0.40 | 0.46 | 0.64 | 0.28 |
| | (0.24) | (0.39) | (0.40) | (0.13) | (0.19) | (0.08) | (0.28) | (0.11) |
| | 2.89 | -2.18 | 0.26 | -2.23 | 2.13 | 5.82 | 2.29 | 2.60 |
| | -1.26 | -4.71 | -2.27 | -9.91 | -3.20 | -6.85 | -1.31 | -6.85 |
| SP | 0.86 | -2.29 | 0.56 | -0.23 | 0.56 | 0.19 | 0.68 | 0.07 |
| | (0.24) | (1.51) | (0.13) | (0.06) | (0.18) | (0.08) | (0.24) | (0.10) |
| | 3.63 | -1.51 | 4.27 | -3.79 | 3.10 | 2.55 | 2.87 | 0.73 |
| | -0.61 | -2.17 | -3.38 | -20.60 | -2.40 | -10.62 | -1.34 | -9.21 |
| UK | 0.44 | -1.65 | 0.12 | -0.22 | 0.22 | 0.19 | 0.37 | -0.04 |
| | (0.16) | (1.48) | (0.17) | (0.08) | (0.15) | (0.08) | (0.13) | (0.05) |
| | 2.77 | -1.11 | 0.72 | -2.84 | 1.50 | 2.55 | 2.90 | -0.86 |
| | -3.47 | -1.79 | -5.09 | -15.80 | -5.30 | -10.74 | -5.04 | -20.67 |

Note:For each country, the first row is the parameter estimate, the second is the standard error, the third the t-statistic for the hypothesis $\beta = 0$ and the fourth for the hypothesis $\beta = 1$

Table 4.5: F-tests results for external variables.

| | 1960-1990 | | | | 1972-1990 | | | |
|---|---|---|---|---|---|---|---|---|
| | USC | USG | USi | Oil P | USC | USG | USi | Oil P |
| B | 10.39 | 10.29 | 11.71 | 11.25 | 1.73* | 1.12* | 0.53* | 1.58* |
| D | 8.95 | 6.92 | 6.61 | 11.01 | 6.94 | 2.86* | 2.09 * | 6.09 |
| F | 5.73 | 5.01 | 4.97 | 4.95 | 0.52* | 0.63* | 0.78* | 0.51* |
| G | 8.16 | 7.19 | 7.05 | 7.03 | 8.13 | 8.29 | 6.11 | 6.12 |
| IR | 1.14* | 2.26* | 7.02 | 0.76* | 0.59* | 3.06* | 6.53 | 0.44* |
| IT | 1.24* | 1.72* | 1.94* | 1.26* | 2.65* | 2.06* | 3.89 | 2.09* |
| GR | 0.55* | 0.67* | 0.08* | 0.53* | 3.48* | 3.21* | 0.59* | 1.17* |
| LU | 4.98 | 5.00 | 4.91 | 5.18 | 1.16* | 1.13* | 1.10* | 1.27* |
| NE | 0.48* | 0.47* | 0.66* | 0.47* | 1.82* | 1.56* | 1.08* | 0.60* |
| PT | 1.27* | 1.53* | 1.55* | 1.20* | 3.24* | 1.81* | 0.73* | 0.35* |
| SP | 0.57* | 0.17* | 0.01* | 0.05* | 0.81* | 0.66* | 0.91* | 0.56* |
| UK | 4.88 | 4.53 | 3.76* | 5.72 | 1.71* | 1.08* | 0.02* | 2.39* |

Note: c.v 3.88. * indicates acceptance of the hypothesis Ho: $\beta_1 = 1$ and $\beta_2 = 0$

Table 4.6: F-tests results for idiosyncratic variables.

| | 1960-1990 | | | | 1972-1990 | | | |
|---|---|---|---|---|---|---|---|---|
| | POP | INF | INC | GOV | POP | INF | INC | GOV |
| B | 11.73 | 9.67 | 17.99 | 12.72 | 1.84* | 2.98* | 6.30 | 5.83 |
| D | 7.51 | 4.94 | 13.98 | 6.72 | 1.87* | 1.41* | 5.39 | 5.05 |
| F | 4.68 | 3.11* | 7.93 | 3.04* | 5.13 | 0.71* | 1.17* | 2.92* |
| G | 5.48 | 6.49 | 11.74 | 6.22 | 2.82* | 4.61 | 6.42 | 2.84* |
| IR | 13.74 | 14.82 | 13.58 | 14.79 | 8.06 | 4.56 | 15.53 | 3.94 |
| IT | 1.06* | 1.69* | 1.21* | 1.41* | 0.64* | 1.40* | 0.74* | 2.07* |
| GR | 0.18* | 2.53* | 4.78 | 0.46* | 0.16* | 2.40* | 1.94* | 0.33* |
| LU | 4.99 | 5.20 | 5.58 | | 1.71* | 1.81* | 5.48 | |
| NE | 0.39* | 0.76* | 3.44 | 2.98* | 0.27* | 2.11* | 0.66* | 2.26* |
| PT | 2.06* | 3.29* | 10.48 | 3.89 | 2.69* | 7.36 | 18.02 | 5.91 |
| SP | 1.87* | 3.15* | 4.73 | 0.90* | 1.49* | 6.66 | 3.45* | 0.63* |
| UK | 3.26* | 4.96 | 4.26 | 3.16* | 0.05* | 2.27* | 0.54* | 0.37* |

Note: c.v 3.88. * indicates acceptance of the hypothesis Ho: $\beta_1 = 1$ and $\beta_2 = 0$

Table 4.7: Variance Decomposition

| | | USC | USG | USi | OP | | POP | INF | INC | GOV |
|---|---|---|---|---|---|---|---|---|---|---|
| EU | 0.58 | 0.07 | 0.06 | 0.13 | 0.16 | 0.71 | 0.10 | 0.04 | 0.03 | 0.13 |
| B | 0.57 | 0.10 | 0.17 | 0.10 | 0.07 | 0.76 | 0.11 | 0.04 | 0.06 | 0.03 |
| D | 0.52 | 0.26 | 0.02 | 0.08 | 0.12 | 0.74 | 0.00 | 0.19 | 0.03 | 0.03 |
| F | 0.78 | 0.01 | 0.02 | 0.17 | 0.01 | 0.59 | 0.02 | 0.01 | 0.30 | 0.07 |
| G | 0.68 | 0.03 | 0.18 | 0.08 | 0.02 | 0.83 | 0.08 | 0.02 | 0.04 | 0.02 |
| IR | 0.63 | 0.15 | 0.03 | 0.13 | 0.06 | 0.30 | 0.19 | 0.09 | 0.16 | 0.27 |
| IT | 0.53 | 0.06 | 0.11 | 0.09 | 0.21 | 0.67 | 0.09 | 0.04 | 0.14 | 0.05 |
| GR | 0.62 | 0.06 | 0.04 | 0.15 | 0.14 | 0.58 | 0.03 | 0.04 | 0.23 | 0.12 |
| LU | 0.61 | 0.05 | 0.12 | 0.07 | 0.15 | 0.89 | 0.05 | 0.03 | 0.03 | 0.00 |
| NE | 0.58 | 0.14 | 0.06 | 0.12 | 0.11 | 0.71 | 0.03 | 0.16 | 0.02 | 0.08 |
| PT | 0.83 | 0.04 | 0.04 | 0.03 | 0.05 | 0.66 | 0.15 | 0.05 | 0.00 | 0.13 |
| SP | 0.45 | 0.12 | 0.11 | 0.17 | 0.15 | 0.96 | 0.02 | 0.02 | 0.01 | 0.00 |
| UK | 0.62 | 0.11 | 0.13 | 0.07 | 0.07 | 0.71 | 0.07 | 0.11 | 0.03 | 0.08 |

Note: The values indicate the percentage of variance after 5 periods that is explained by each variable. The first and sixth columns indicate the percentage of variance not affected by the exogenous variables

Table 4.8: Granger-Causality Test.

| | USC | USG | USi | OILP | Block |
|---|---|---|---|---|---|
| EU | 0.43 | 4.04 | 1.12 | 2.65 | 18.66 |
| B | 5.63 | 10.07 | 3.77 | 0.89 | 18.08 |
| D | 7.65 | 3.04 | 6.59 | 10.49 | 28.10 |
| F | 1.35 | 4.60 | 7.38 | 1.28 | 10.88 |
| G | 13.96 | 8.81 | 2.88 | 0.01 | 20.72 |
| IR | 5.87 | 0.84 | 2.84 | 1.12 | 27.74 |
| IT | 6.47 | 7.57 | 1.02 | 2.93 | 44.58 |
| GR | 7.27 | 8.07 | 16.25 | 7.50 | 22.41 |
| LU | 1.99 | 3.17 | 6.78 | 8.04 | 18.50 |
| NE | 8.95 | 3.83 | 0.08 | 4.90 | 23.99 |
| PT | 2.72 | 3.59 | 0.55 | 2.53 | 9.32 |
| SP | 14.55 | 10.58 | 8.58 | 8.71 | 37.51 |
| UK | 4.65 | 4.27 | 1.03 | 3.67 | 18.66 |
| | POP | INF | INC | GOV | Block |
| EU | 1.99 | 1.98 | 1.84 | 4.94 | 9.50 |
| B | 0.34 | 1.57 | 6.12 | 0.65 | 12.25 |
| D | 0.12 | 7.57 | 1.90 | 2.09 | 16.67 |
| F | 12.61 | 23.19 | 9.10 | 4.08 | 39.89 |
| G | 1.85 | 3.45 | 2.94 | 0.51 | 7.81 |
| IR | 20.08 | 4.59 | 53.98 | 33.02 | 90.47 |
| IT | 6.25 | 5.21 | 5.08 | 4.75 | 10.44 |
| GR | 4.27 | 27.57 | 35.32 | 6.48 | 19.41 |
| LU | 0.92 | 1.14 | 1.28 | 0.00 | 6.62 |
| NE | 3.78 | 6.94 | 0.26 | 3.64 | 13.37 |
| PT | 5.81 | 4.24 | 3.21 | 2.14 | 18.15 |
| SP | 0.20 | 1.11 | 0.04 | 0.07 | 1.36 |
| UK | 0.37 | 3.16 | 2.08 | 4.33 | 16.86 |

Note:Individual test c.v.5.99. Block test c.v.:15.51

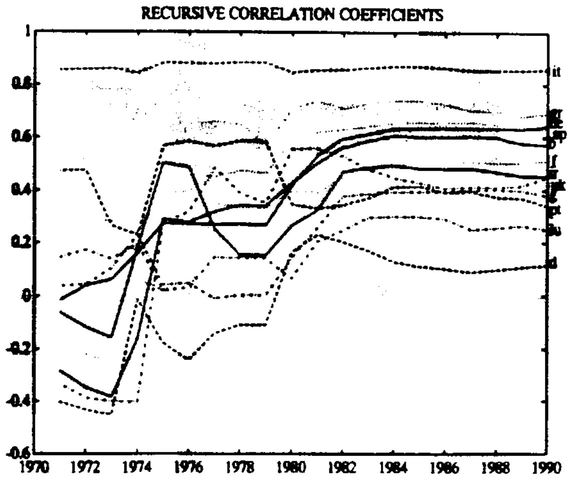


Figure 4.1: Recursive correlation coefficents

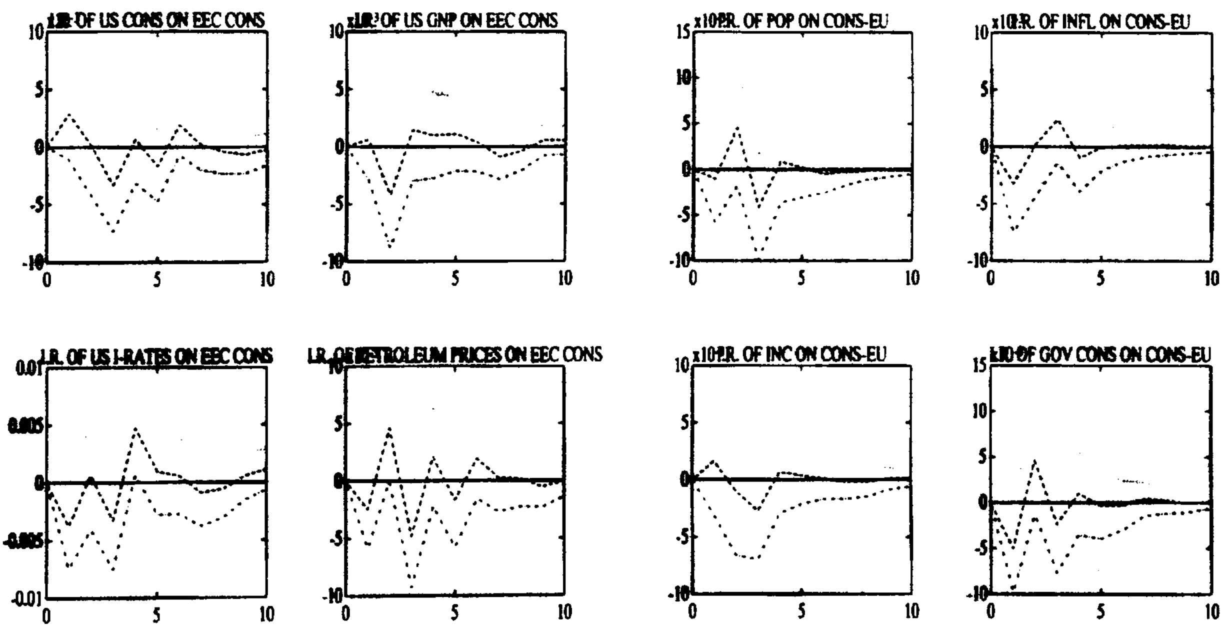


Figure 4.2: Impulse responses of EU to external and idiosyncratic shocks

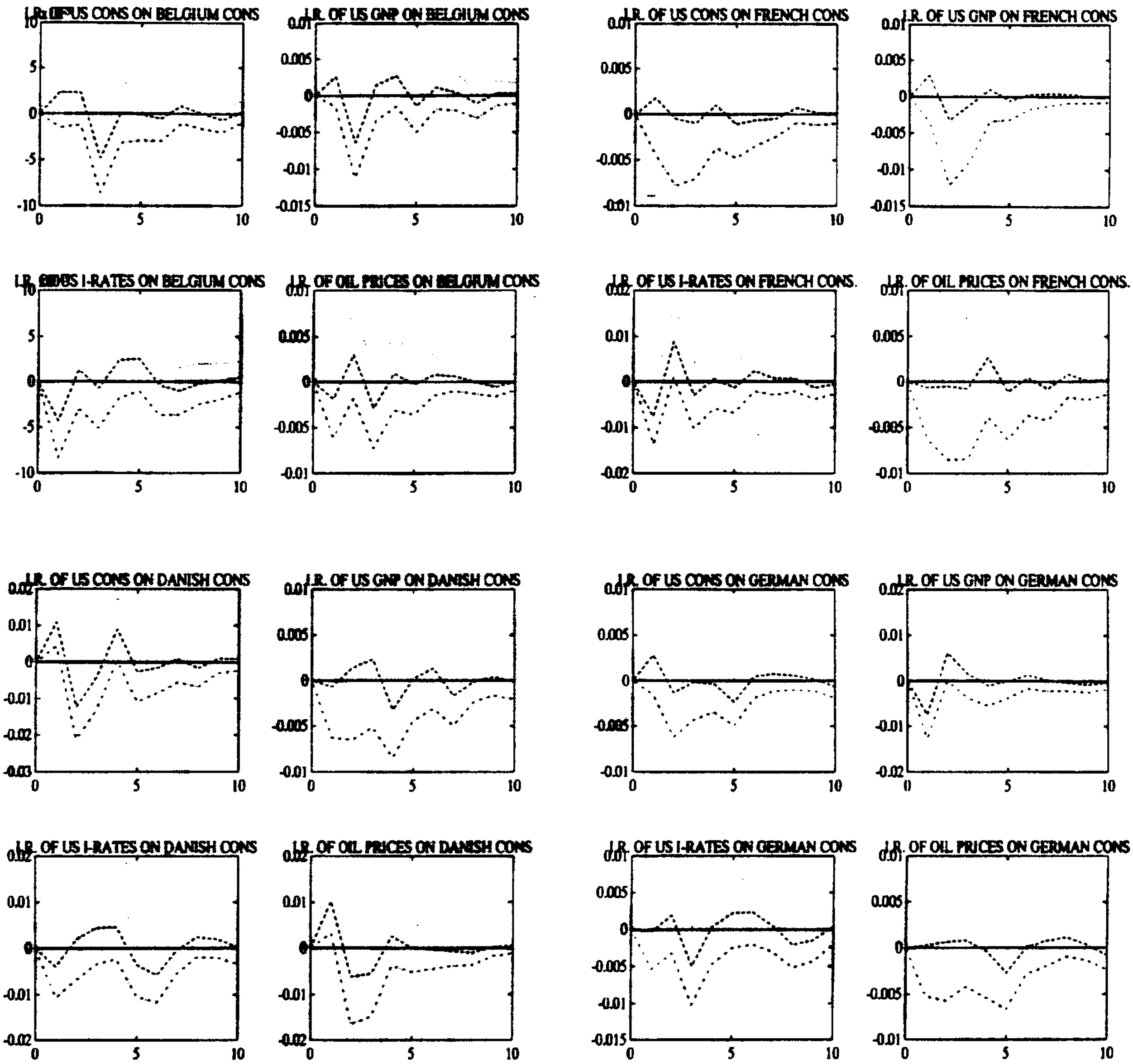


Figure 4.3: Impulse responses of EU countries to common external shocks

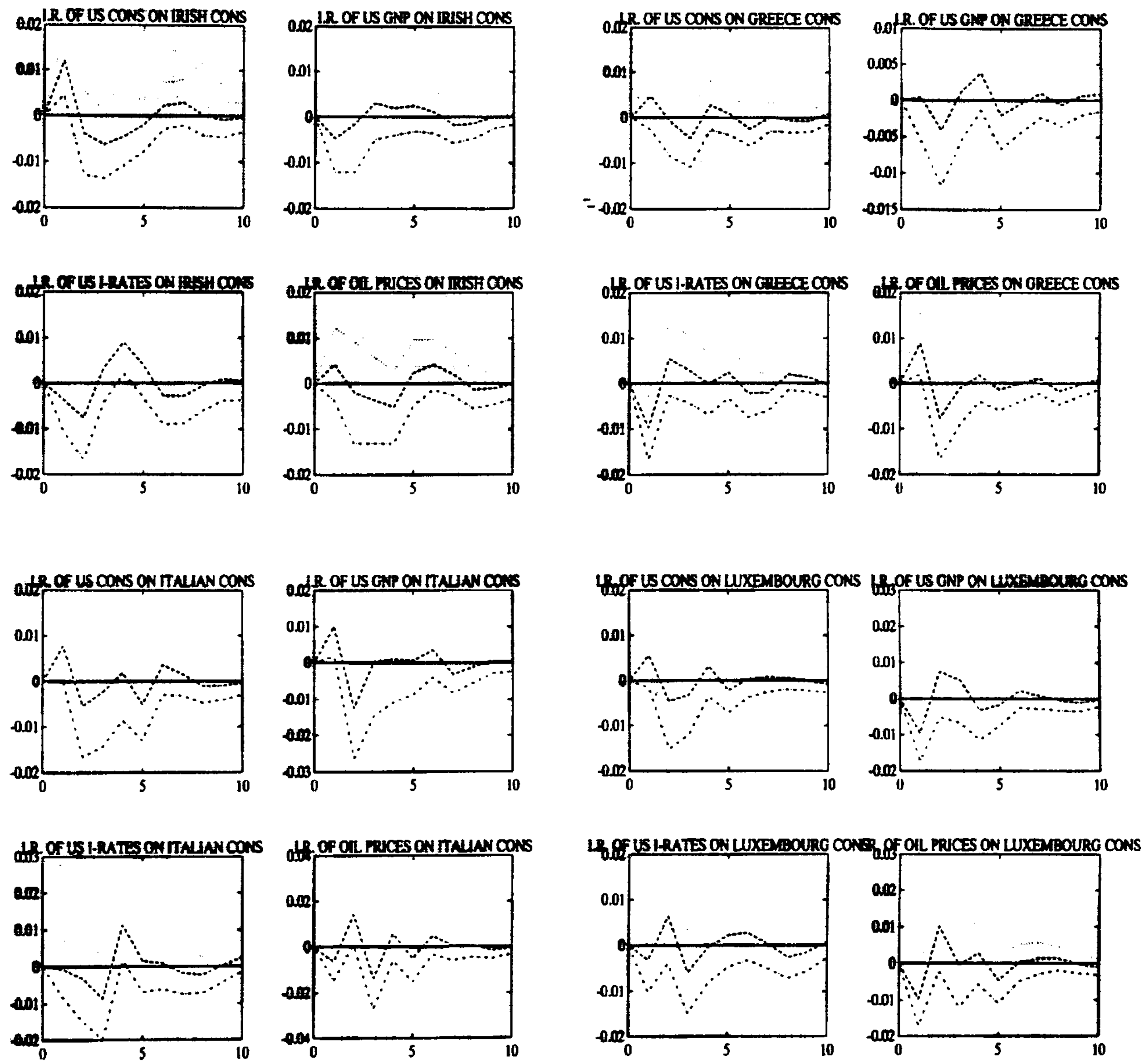


Figure 4.4: Impulse responses of EU countries to common external shocks

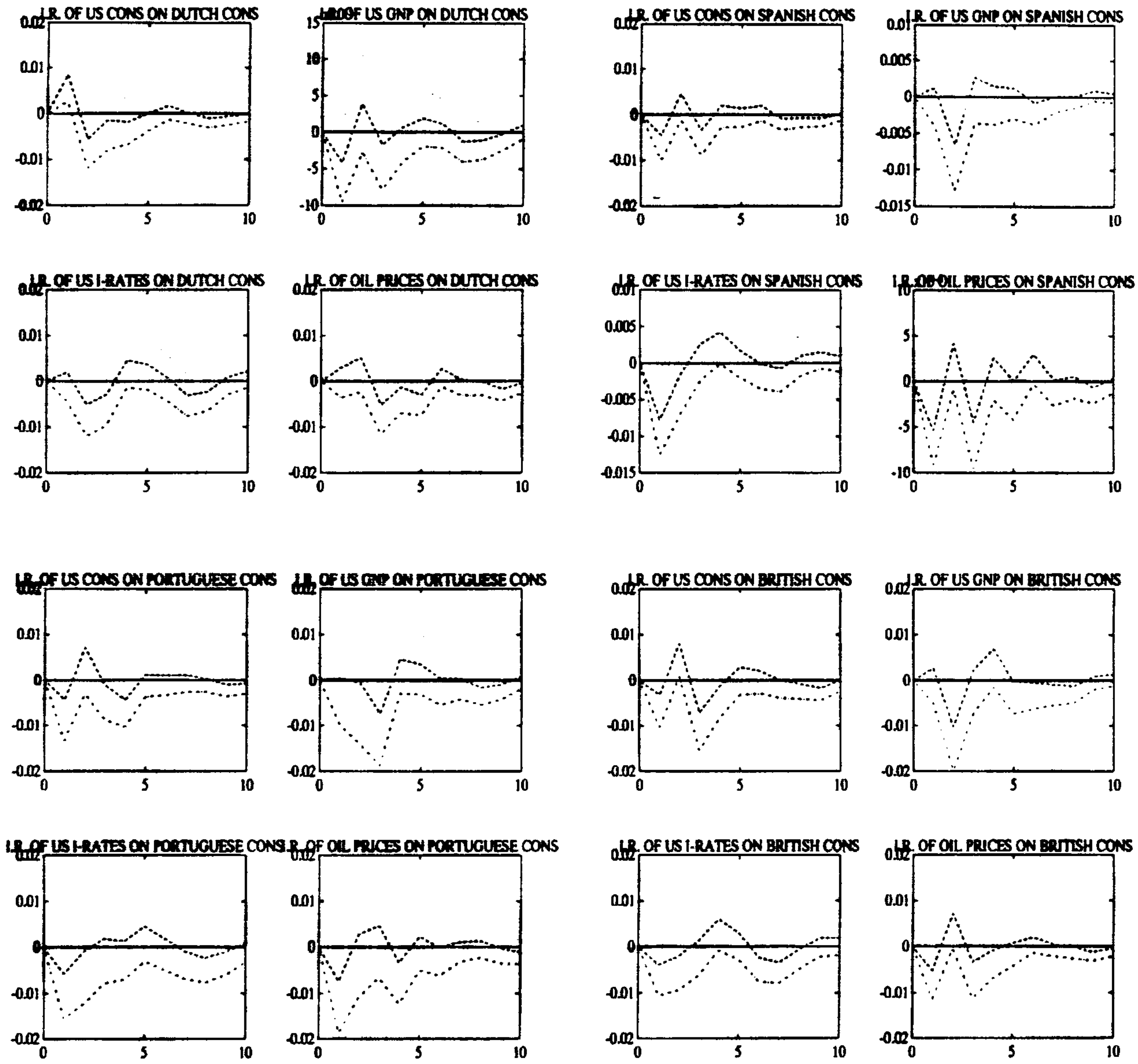


Figure 4.5: Impulse responses of EU countries to common external shocks

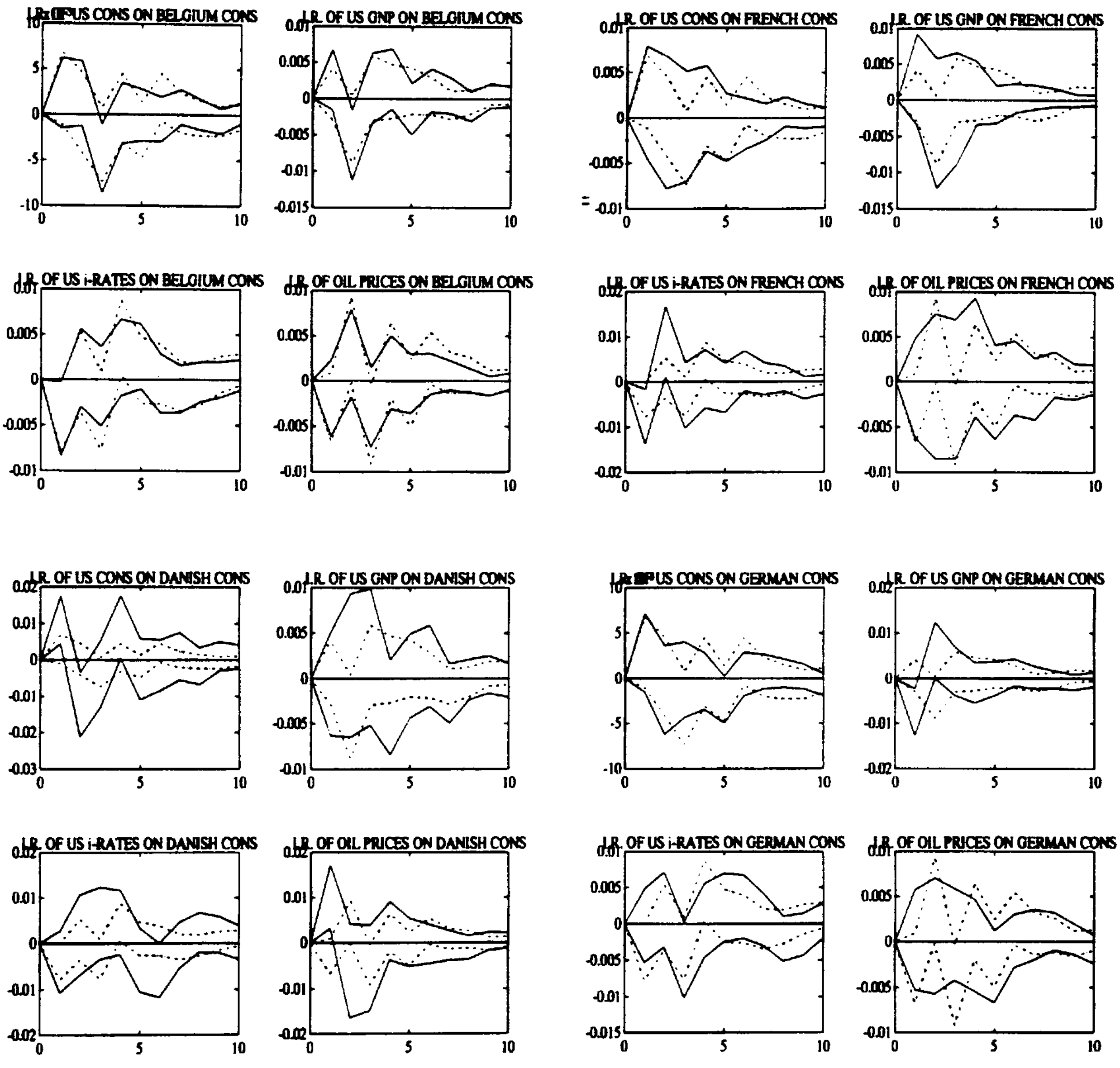


Figure 4.6: S.E bands of EU and each country responses to common shocks

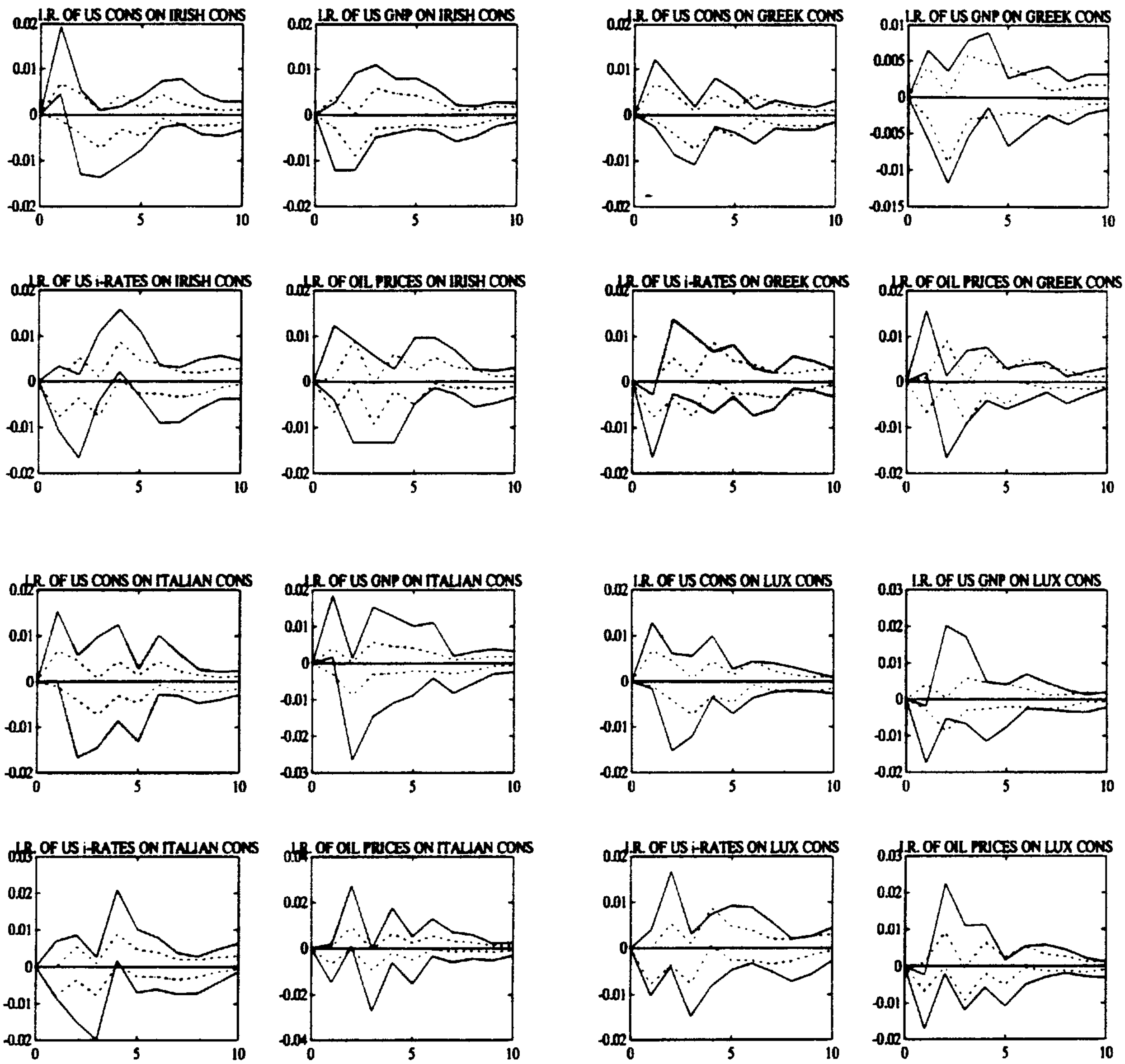


Figure 4.7: S.E bands of EU and each country responses to common shocks

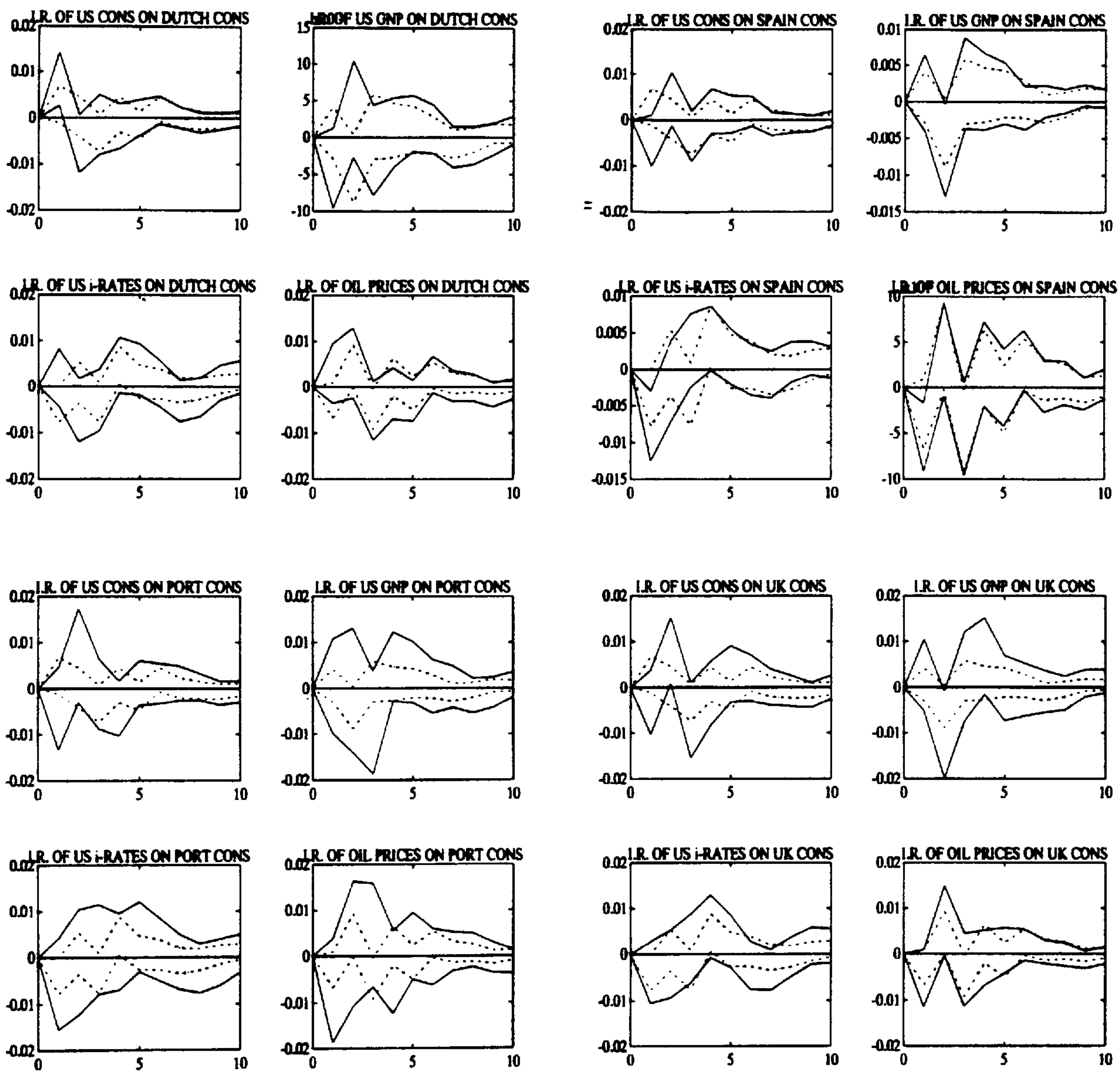


Figure 4.8: S.E bands of EU and each country responses to common shocks

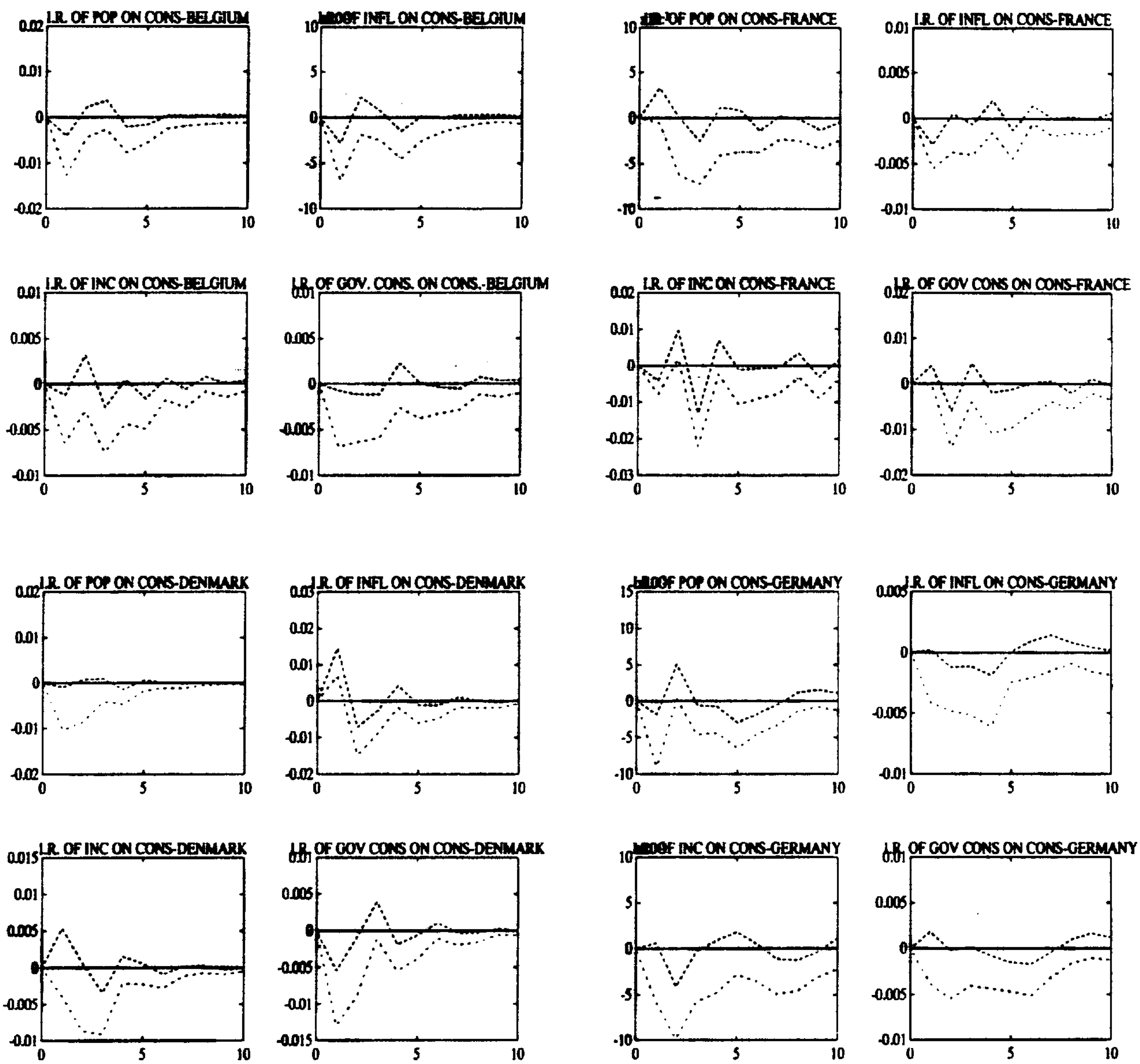


Figure 4.9: Impulse responses of EU countries to idiosyncratic shocks

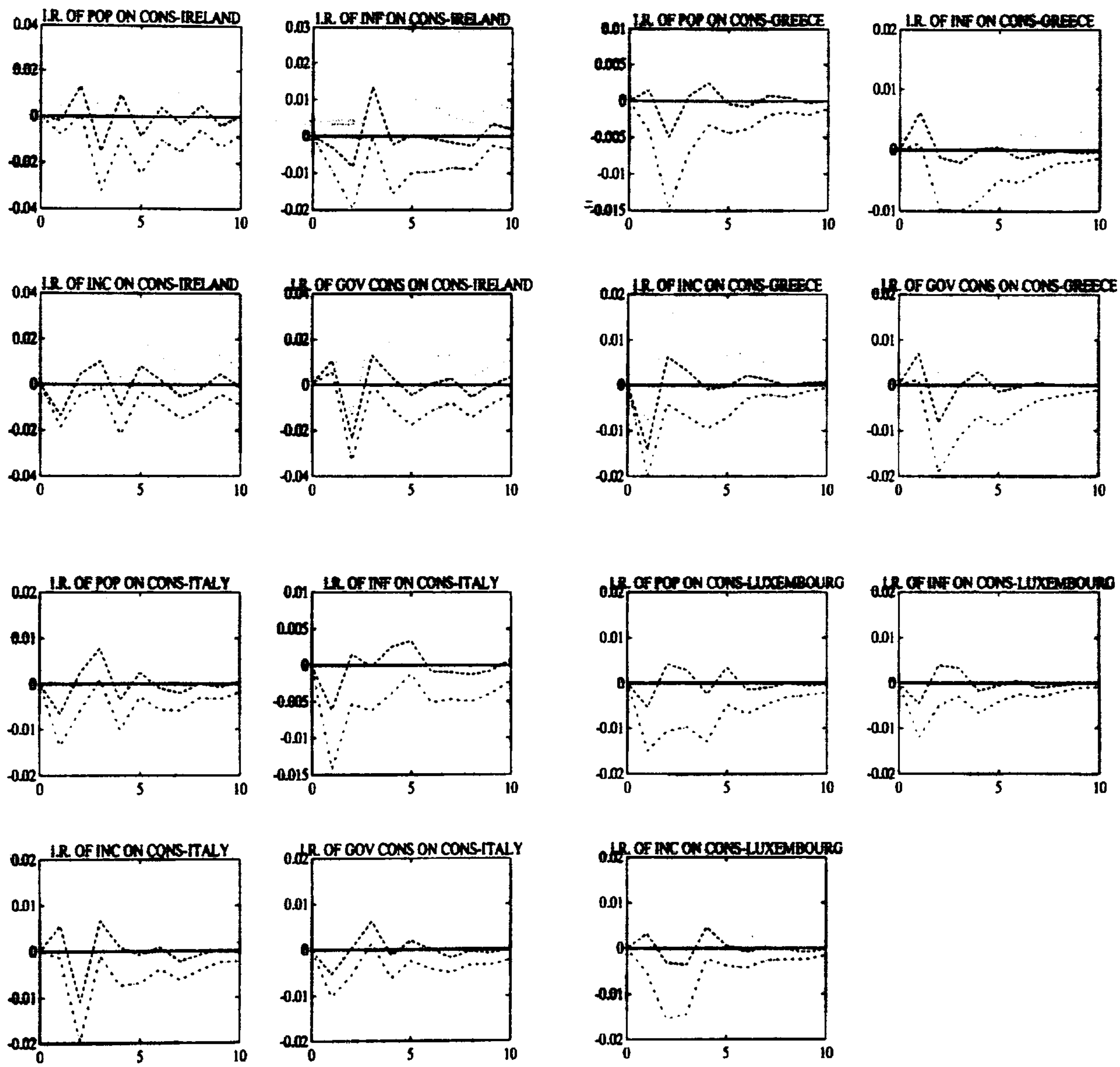


Figure 4.10: Impulse responses of EU countries to idiosyncratic shocks

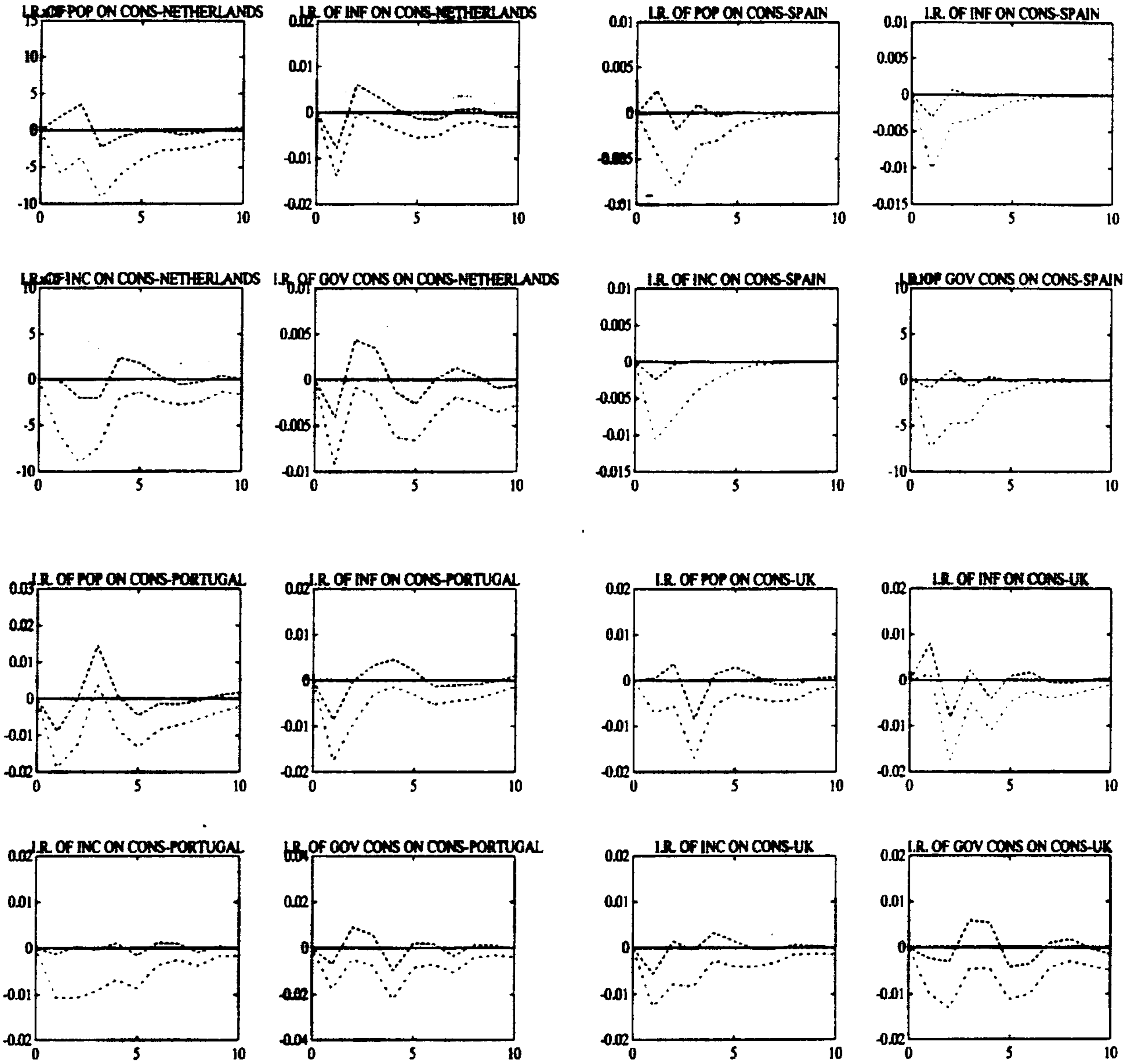


Figure 4.11: Impulse responses of EU countries to idiosyncratic shocks

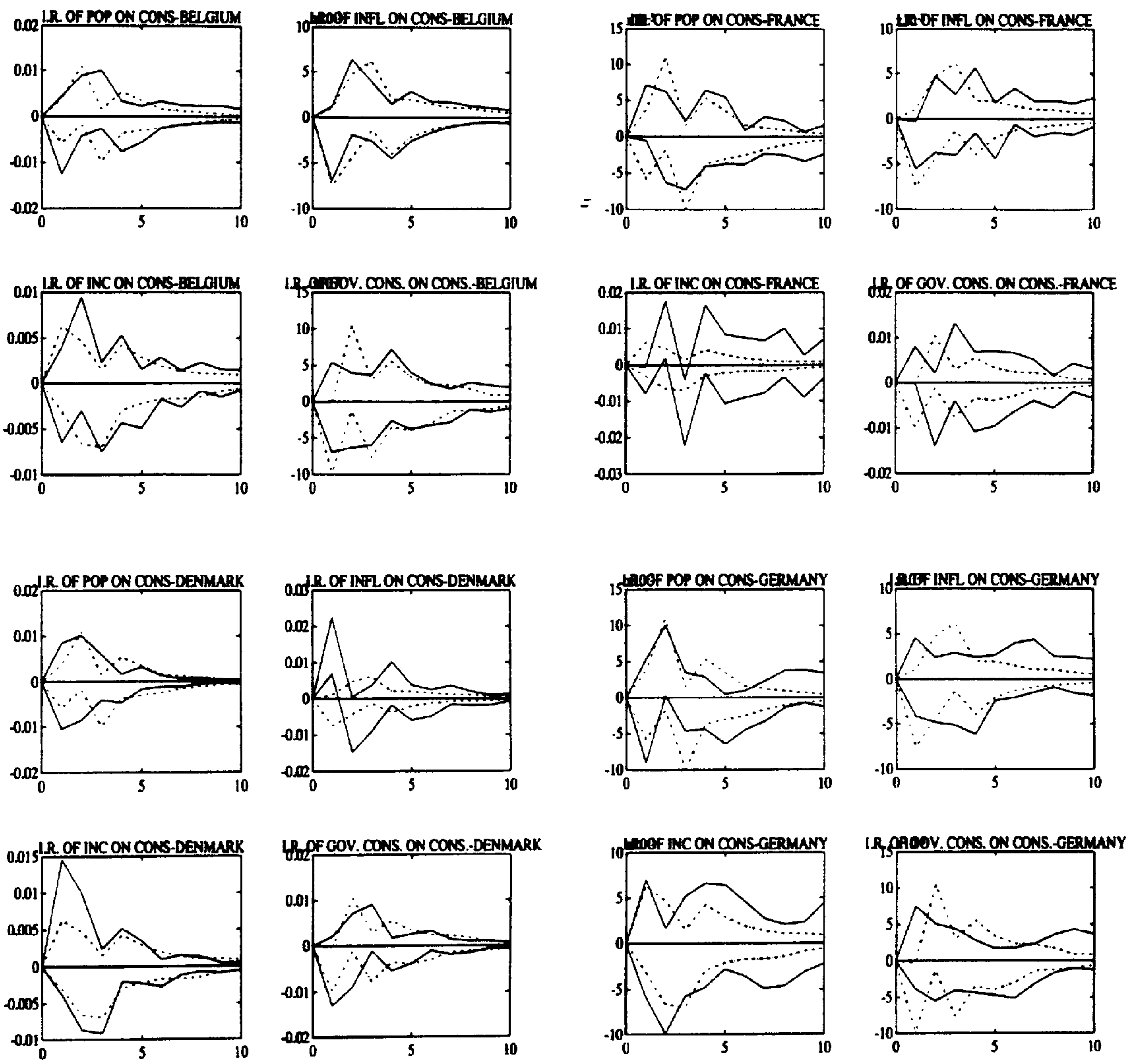


Figure 4.12: S.E bands of EU and each country responses to idiosyncratic shocks

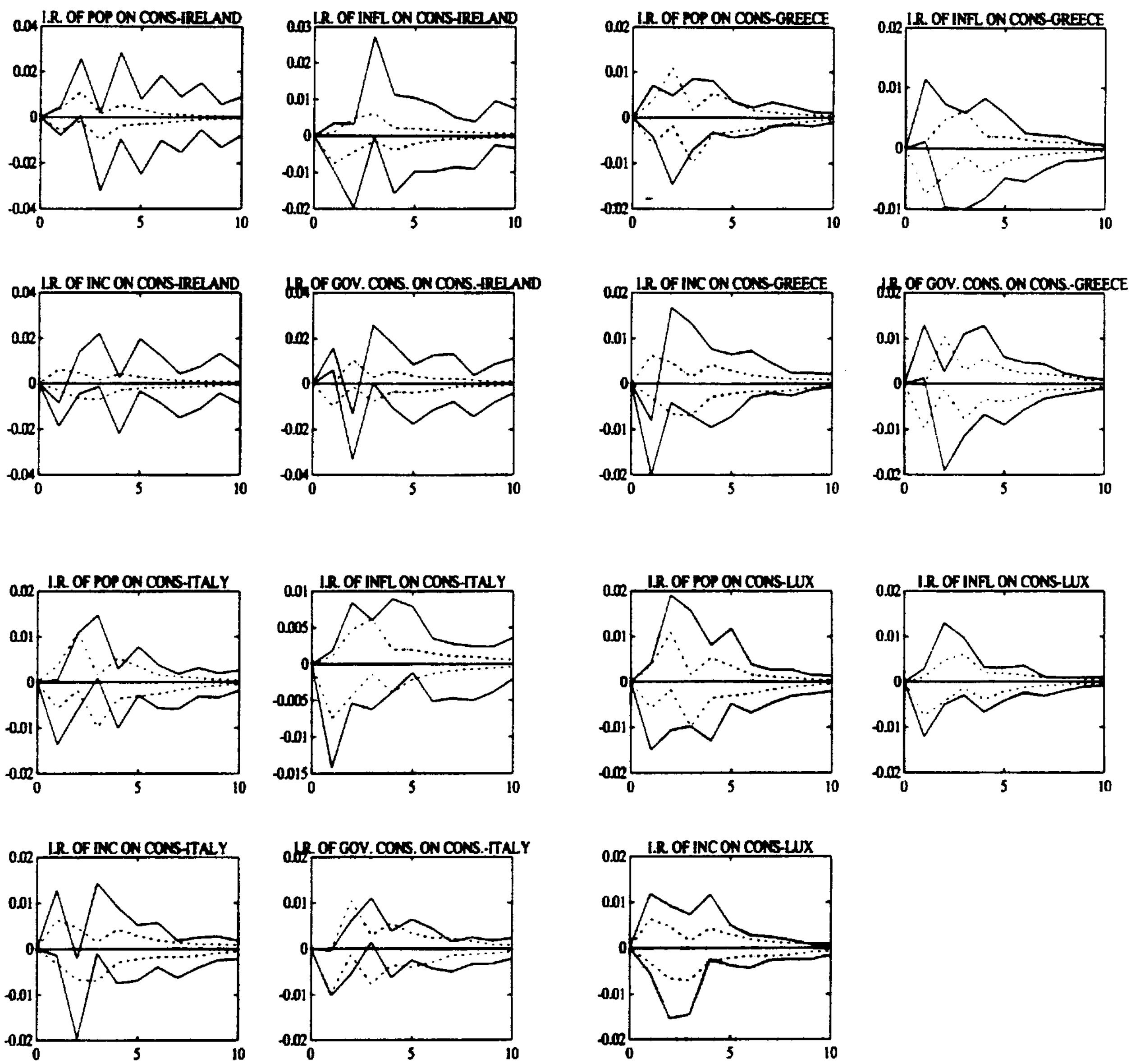


Figure 4.13: S.E bands of EU and each country responses to idiosyncratic shocks

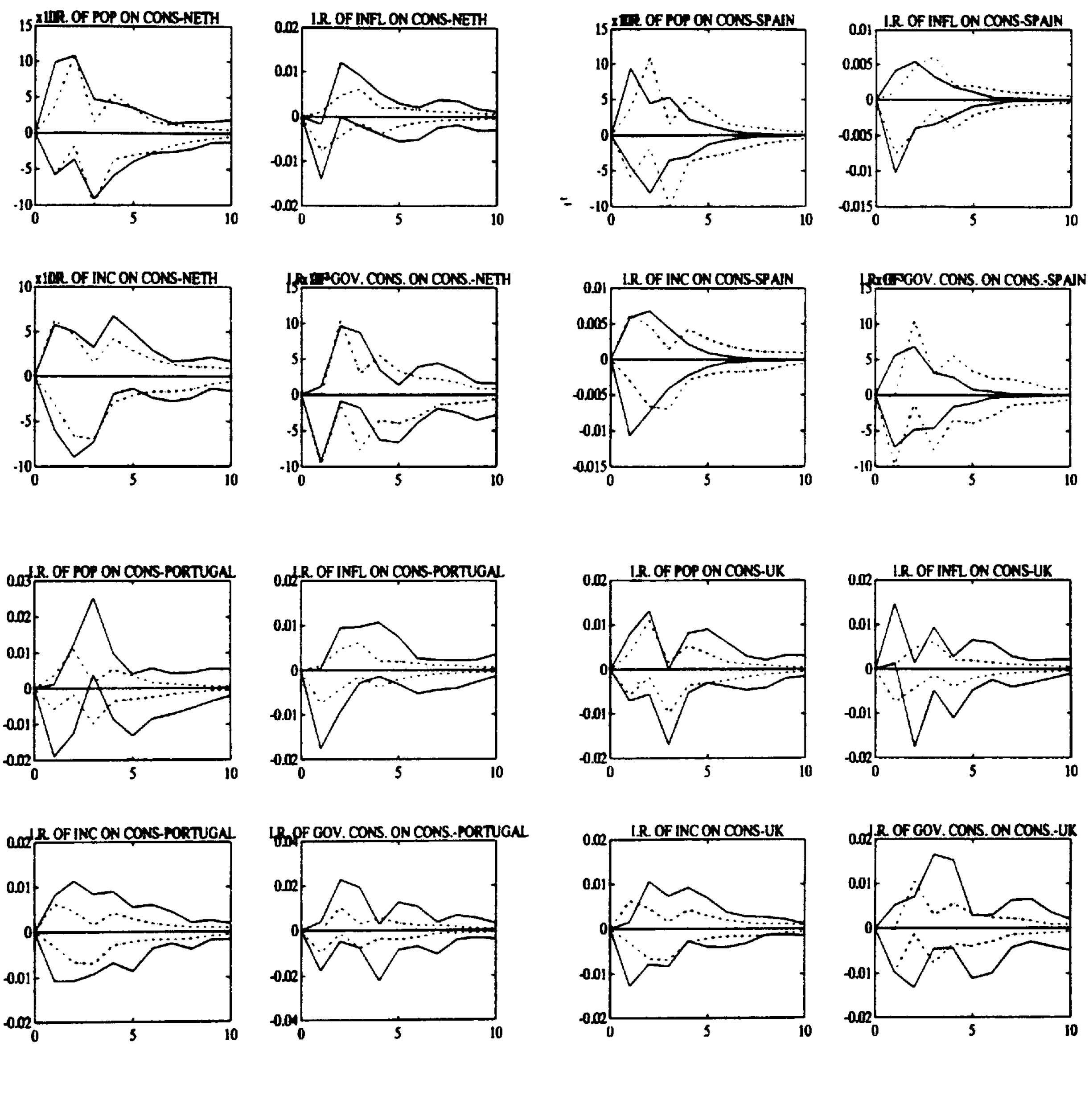


Figure 4.14: S.E bands of EU and each country responses to idiosyncratic shocks

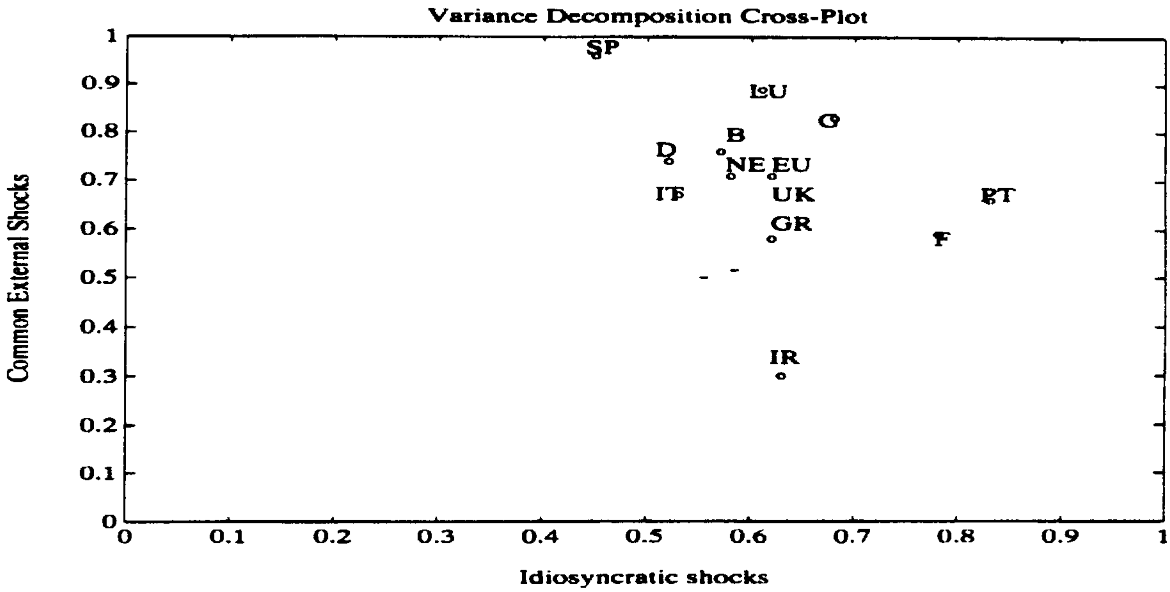


Figure 4.15: Variance Decomposition Cross-Plot: Percentage of variance not due to shocks

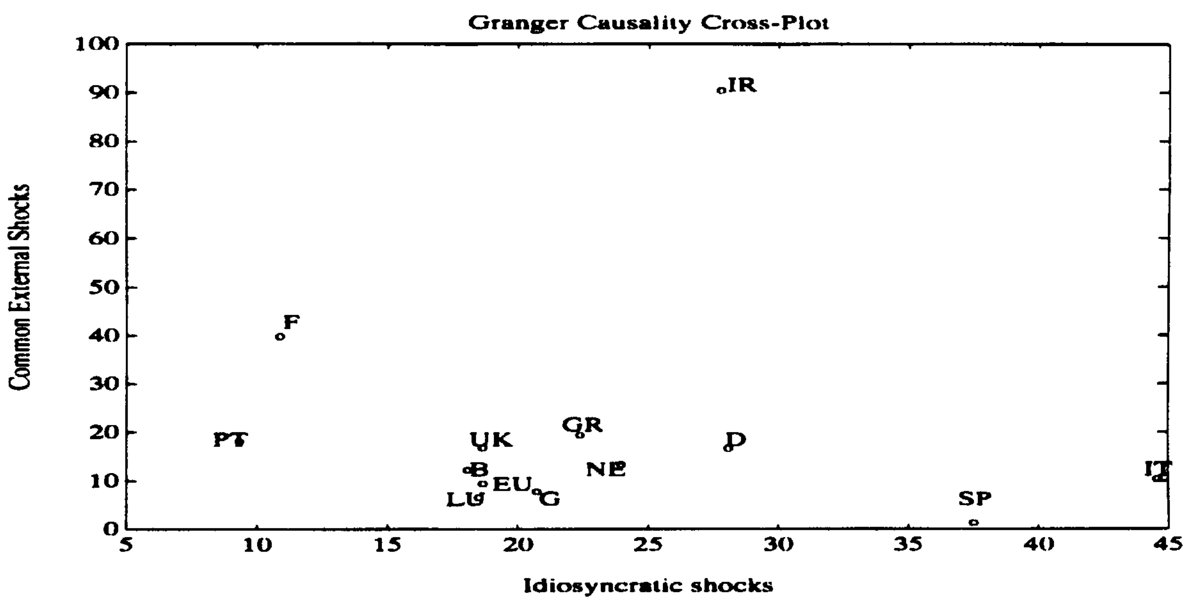


Figure 4.16: Block Granger-Causality Cross-Plot

# Conclusion

This thesis has analyzed from both a theoretial and an empirical point of view the cyclical behaviour of OECD economies. We have empirically characterized the typical business cycle of developed economies and have given a theoretical content to the main stylized facts. Our theoretical apparatus has been the open economy extension of the Real Business cycle research program. We have first introduced the methodology and basic assumptions of this research program and then explained them in some detail. After presenting a benchmark international business cycle model and pointing out its main failures in replicating the stylized facts, we have consecutively introduced two theoretical modifications intended to improve its behavior. The first one has consisted of breaking the assumption of perfect competition by introducing increasing returns to scale at the firm's level and monopolistic competition in national product markets. We have studied the implications of this feature for issues like the effects of technology shocks or the international transmission of fiscal policies. The second modification has been the introduction of household production in the model. Household production implies altering one of the crucial properties of the model, the labor/leisure substitution. Both modifications have improved the behaviour of the standard model in several ways, and in particular the second makes the model replicate the main stylized facts of international business cycles. Only the volatility of foreign trade variables remains unexplained. Finally, we have empirically studied one of the main issues in international business cycles, the risk sharing properties of the economies. We have applied it to the European Union because of its implications for the design of optimal currency areas. The results indicate that the degree of risk sharing existing in the European Union is relatively high.

Summarizing, our results indicate that the cyclical behaviour of OECD economies is quite similar and that we cannot neglect neither the demand side of the economy, in particular consumer preferences, nor the existence of imperfect competition, in any attempt to understand the fluctuations of developed economies.

This thesis has improved in several ways our understanding of the international business cycle, but there remain several unexplained puzzles. Perhaps the most important regards the volatility of foreign trade variables, and in particular the terms of trade. There are some directions along which models could be extended in order to solve these puzzles. One of then could be to break the assumption of perfect competition in international trade, extending, for example, the economy of Dixit and Stiglitz (1977) to the open economy framework. Another direction could be to break the assumption of symmetric information and make use of some of the results that contract theory offers. The recursive characterization of contracts of Marcet and Marimon (1995) could be a first step in this direction.

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