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Dynamic Effects of Demand and Supply Disturbances on the Finnish Economy: Did Liberalization of Capital Movements Matter?

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Abstract

The purpose of this study is to analyze the dynamic effects of demand and supply disturbances on the Finnish economy. In addition, the study aims at finding out whether liberalization of capital movements affected the transmission of disturbances. The analysis is based on a vector autoregressive model for unemployment and the GNP from 1970.1 to 1990.4. The vector autoregressive representation is then transformed to a corresponding moving average representation and the dynamic effects of disturbances are analyzed by impulse response functions. The model restricts the number of disturbances to two, called demand and supply disturbances. Estimation shows that demand disturbances have temporary effects on GNP and unemployment, the effects of supply disturbances on GNP are permanent but their effects on unemployment are temporary. As capital mobility increases the effects of demand disturbances die out faster. There is no significant difference in the short term effects of supply disturbances on GNP but the long term effects are magnified. This is in accordance with economic theory.

Tiivistelmä

Tutkielman tavoitteena on tutkia kysyntä- ja tarjontahäiriöiden välittymistä Suomen taloudessa. Työttömyydelle ja BKT:lle aikavälillä 1970.1–1990.4 rakennetun vektoriautoregressiivisen mallin avulla tutkitaan myös pääomaliikkeiden vapauttamisen mahdollisia vaikutuksia häiriöiden välittymiseen. Häiriöiden dynaamisia vaikutuksia tutkitaan impulssivasteiden avulla, jotka saadaan konstruoimalla VAR-mallia vastaava liukuvan keskiarvon (MA-) esitys. Mallissa on ainoastaan kahdenlaisia häiriöitä, kysyntä- ja tarjontahäiriöitä. Kysyntä- ja tarjontahäiriöiden dynaamiset vaikutukset talouden kokonaistuotantoon ja työttömyyteen poikkeavat merkittävästi toisistaan. Siinä missä kokonaiskysyntähäiriöiden vaikutukset kokonaistuotannon tasoon ja työttymyyteen ovat väliaikaisia, kokonaistarjontahäiriöillä on pysyviä vaikutuksia kokonaistuotantoon, mutta väliaikaisia vaikutuksia työttömyyteen. Pääomaliikkeiden lisääntyessä kysyntähäiriöt vaimenevat aiempaa nopeammin. Tarjontahäiriöiden lyhyen aikavälin vaikutukset kokonaistuotantoon pysyvät kutakuinkin ennallaan mutta pitkän aikavälin vaikutukset vahvistuvat. Tältä osin tulokset ovat sopusoinnussa talousteorian kanssa.

Contents

1 Introduction

The purpose of the study is to analyze the dynamic effects of demand and supply disturbances on the Finnish economy. Distinction between domestic and foreign disturbances is not made, the study concentrates on the combined effect of foreign and domestic demand and supply disturbances on the economy. In addition, the study aims at finding out whether the liberalization of capital movements affected the transmission of disturbances.

The study is done by first constructing a vector autoregressive model (VAR) for unemployment and GNP from 1970 to 1990. The vector autoregressive representation is then transformed to a corresponding moving average representation and the dynamic effects of disturbances are analyzed by impulse response functions. The model restricts the number of disturbances to two, called demand and supply disturbances. Disturbances are identified so that demand disturbances have temporary effects on output, supply disturbances can have permanent effects on output and both have only temporary effects on unemployment.

The responses are first analyzed for the period 1970–1990 and then separately for the periods 1970–1983 and 1984–1990. The results are presented and analyzed accordingly.

The liberalization process in the Finnish capital markets is briefly described in chapter 2. Chapter 3.1 presents the model based on a study by Blanchard and Quah (1992), chapter 3.2 explains the principles of vector autoregression, chapter 3.3 contains data analysis and chapter 3.4 presents the results of the empirical study. Chapter 4 presents the theoretical interpretation for the transmission of disturbances in the familiar framework of the Mundell–Fleming model. Finally, concluding remarks are presented in chapter 5.

2 Liberalization of Finnish capital markets

The Finnish capital markets were controlled for decades until the slow liberalization process started in 1980. The aim of this chapter is to first give some reasons for capital controls and then to describe the liberalization process of the Finnish capital markets.

2.1 Objectives of capital controls

In the 1960's and 1970's the prevailing view was that capital controls were needed to ensure the necessary protection against adverse shocks and to preserve the independence of national policies. Monetary policy in particular was used in many countries to serve two objectives simultaneously: full employment and a stable monetary order within the framework of the Bretton Woods system of fixed exchange rates. Despite the collapse of the Bretton Woods system in the early 1970's, controls were maintained in many countries until well into the 1980's.[1] Two possible reasons for capital controls are presented here.

Weak currency

The most widespread justification for capital controls was to counter market pressures for a depreciation of the exchange rate without the need for a rise in domestic interest rates. For countries that declare the achievement of a stable exchange rate to be the key objective of policy, a devaluation is the most visible manifestation of policy failure. Therefore, controls were maintained by precaution in potentially weak currency countries.[2]

Inflationary capital inflows

In a fully integrated financial world capital would flow from lower return markets to markets offering more attractive returns. This excessive inflow of capital can be inflationary. During the 1980's, macroeconomic stabilization programmes in Finland among others (e.g. Norway, Portugal and Spain) were accompanied by restrictions of capital inflow attracted by high interest rates resulting from an unbalanced mix of tight monetary policy and loose fiscal policy. The main objective of these controls was to prevent the capital inflows, too large to be sterilized, from spurring already strong inflationary pressures.

2.2 Capital controls in Finland

The Finnish capital markets were controlled for decades until the slow liberalization process started in the early 1980s. Most of the capital controls were controls on long-term capital movements (loans and investments). This means that a permit to import or export capital was needed. Short-term capital movements with a commercial base were usually free. Table 2.1 below describes the position as of December 1980 when capital movements were still largely controlled.

When the Finnish financial markets started to evolve and new financial instruments were introduced, capital controls lost their power. An important event was the withdrawal of the Bank of Finland from the forward markets in 1980, allowing for the markets to evolve by themselves. Until that moment the central bank had a crucial role in the determination of the forward exchange rate. Nyberg (1992) makes clear that, once a forward exchange market was put in place to allow enterprises to cover their foreign exchange risks it became much more difficult to insulate the domestic money market from international interest arbitrage.

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[1] OECD, pp. 10–11.

[2] OECD pp. 11–14.

The liberalization process continued throughout the 1980s. The most important steps are summarized in Table 2.2. By October 1991 the capital markets were free of all regulations, the last abolishment concerning exchange controls on the contracting of loans by private individuals and comparable corporate entities.

Table 2.1 **Position as of December 1980**

* Foreign exchange for **import payments** is granted by authorized banks for all permitted imports on presentation of an application form.
* Exporters are required to repatriate **foreign exchange proceeds** within eight days of collection, which may be held in a foreign currency account.
* Most **outward transfers of nonresident capital** are subject to approval by the Bank of Finland.
* Nonresidents may purchase bonds, debentures, or shares quoted on the Helsinki Stock Exchange through an authorized bank, against convertible currencies or by debiting a convertible account. **Proceeds from the sale of such securities** may be repatriated in a convertible currency. Any other transactions in securities, and the export of securities that involve nonresident interests, require approval.
* **Inward direct investments** must be approved by the Bank of Finland. Approval is usually granted, unless the investment is judged to be exceptionally detrimental to the national interest or to be of a **purely financial character**.
* **Outward transfers of capital**, including transfers for direct investment by residents, require individual approval.
* **Foreign currency borrowing** by Finnish residents, in the form of short-term or medium-term financial credits or by bond issues abroad, requires the specific approval of the Bank of Finland, which exercises surveillance over the terms and timing.

Source: IMF Annual Report on Exchange Arrangements and Exchange Restrictions 1981

Table 2.2 Liberalization process summarized

1980	The Bank of Finland discontinued the quotation of forward rates for the U.S. dollar. New guidelines for commercial banks concerning the forward market were issued.
1981–	The limits for exporting capital by individuals were gradually eased.
1985	Forward exchange markets were liberalized considerably, firms were granted the right to hedge the difference between their foreign currency claims and liabilities.
1986	The Bank of Finland exempted from regulations foreign credits with a maturity of at least five years raised by manufacturing and shipping companies for financing their own operations.
1987	The exemption from the regulation of foreign credits was extended to companies or cooperative societies that are engaged in business activity.
1988	The Bank of Finland relaxed restrictions on direct investment, and on purchases of foreign securities. Direct foreign investment by nonfinancial enterprises no longer requires special permission from the Bank of Finland.
1989	The regulations on outward and inward capital transfers were broadly liberalized. Nonfinancial institutions were permitted to obtain foreign loans of more than one year's maturity, and most direct investments in Finland no longer require authorization by the Bank of Finland.
1990	Sales abroad of markka-denominated bonds with maturities exceeding one year were authorized, enabling foreign borrowing without exchange risk. The Bank of Finland exempted Finnish companies' share issues abroad from the requirement of prior authorization. Finance companies were permitted to apply for the right to intermediate and raise foreign loans (previously only deposit banks were accorded this right). Private persons were permitted to undertake foreign investments and to grant loans of over one year's maturity to nonresidents without limit. (This liberalization measure would also apply to corporate entities considered comparable to private persons.)
1991	All remaining foreign exchange controls were abolished.
Sources:	IMF Annual Report on Exchange Arrangements and Exchange Restrictions 1981–1992.

3 A small macroeconomic model and its empirical estimations

3.1 The model

The purpose of this study is to analyze the dynamic effects of aggregate demand and supply disturbances. The model is constructed following an article by Blanchard and Quah (1989).

Economic Interpretation

Blanchard and Quah adopted an approach where they assume that there are two types of disturbances, each uncorrelated with the other, and that neither type of disturbance has a long-run effect on unemployment. The first disturbances have long-run effects on output but the second ones do not. These assumptions identify the two types of disturbances and their dynamic effects on output and unemployment.

The disturbances that have a temporary effect on output are interpreted as mostly **demand disturbances** and those that have a permanent effect on output as mostly **supply disturbances**. This view is motivated by a traditional Keynesian view of fluctuations. Let

$$Y(t) = M(t) - P(t) + a\theta(t) \tag{3.1}$$

$$Y(t) = N(t) + \theta(t) \tag{3.2}$$

$$P(t) = W(t) - \theta(t) \tag{3.3}$$

$$W(t) = W \,|\, \{E_{t-1}N(t) = \bar{N}\} \tag{3.4}$$

where Y, N and θ denote the logarithm of output, employment and productivity, respectively. P is the logarithm of the price level and W of the nominal wage. E_{t-1} denotes expectations made in period t−1.

Equation (3.1) states, that aggregate demand is a function of real money balances (M(t) − P(t)) and of productivity. Productivity can affect aggregate demand directly, e.g., through investment demand ($a > 0$). Equation (3.2) is the production function. It relates output, employment and productivity. Equation (3.3) gives the price level as a function of the nominal wage and productivity, and equation (3.4) characterizes the wage-setting behaviour in the economy: the wage is chosen one period in advance and is set so as to achieve full employment. Further

$$M(t) = M(t-1) + e_d(t) \tag{3.5}$$

$$\theta(t) = \theta(t-1) + e_s(t) \tag{3.6}$$

where e_d and e_s are the serially uncorrelated and pairwise orthogonal demand and supply disturbances.[3] Equations (3.5) and (3.6) state that money balances and productivity are functions of their past values and of demand and supply disturbances, respectively. When unemployment is defined to be $\bar{N}-N$, solving for unemployment U and output Y gives

$$\Delta Y = e_d(t) - e_d(t-1) + a(e_s(t) - e_s(t-1)) + e_s(t)$$

$$U = -e_d(t) - ae_s(t)$$

Demand disturbances e_d have short run effects on both output and unemployment, but these effects disappear over time. In the long run only supply disturbances e_s affect output. Neither of the disturbances has a long-run impact on unemployment.

We now turn tot he vector autoregressive model (VAR).

3.2 The VAR methodology

Vector autoregression (VAR) is a system where all the variables are endogenous and each can be written as a linear function of its own lagged values and the lagged values of all the other variables in the system. If all the variables are gathered into a single vector, this can be viewed as a vector autoregression. This vector is expressed as a linear function of its own lagged values plus an error vector.[4] Estimation is done by running a separate regression for each variable, regressing it on lags of itself and all other variables.[5]

The vector autoregression equation is then inverted (to a moving average form) to express the vector of current values of the variables in terms of current and lagged values of the error vector. This representation is then transformed into an orthogonal form in which the vector of current values of the variables is expressed as a linear function of current and lagged values of a vector of orthogonal innovations.

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[3] Orthogonality means that the vectors are perpendicular to each other, formally $e_i'e_i = 1$ and $e_i'e_j = 0$.

[4] Kennedy (1992) pp. 162–163.

[5] If the residuals are correlated running separate regressions for each variable leads to loss of information.

In this context, a vector autoregressive model is used to analyze the effect an unexpected change in one variable (a shock) has on the variable itself and on all other variables. The measure of this effect is called an impulse response.

Formally, vector autoregression may be written

$$x_t = \sum_{i=1}^{2} B_i y_{t-i} = u_t \qquad E(u_t u'_t) = \Sigma \tag{3.7}$$

where x is a 2-vector of output and unemployment and B_i is an 2 x 2 matrix. Σ is the covariance matrix of the errors.[6]

The moving average representation of the model is obtained by first estimating (3.7) and then inverting it.

Methodology

Let X_t denote a vector of variables, y_t and u_t, the logarithm of output and the rate of unemployment, respectively. Let e_d and e_s be again the two disturbances. The impulse response functions of the shocks to the elements of X_t can be written as:

$$X_t = A_0\varepsilon_t + A_1\varepsilon_{t-1} + A_2\varepsilon_{t-2} + A_3\varepsilon_{t-3} + \dots \tag{3.8}$$

$$X_t = \sum_{i=0}^{\infty} L^i A_i \varepsilon_t$$

where L is the lag operator and the matrices A_i are the impulse response functions. The terms ε_t represent the vector of the shocks to the model.

The model can be written in terms of the specified vectors and the demand and supply disturbances:

$$\begin{bmatrix} y_t \\ u_t \end{bmatrix} = \sum_{i=0}^{\infty} L^i \begin{bmatrix} a_{11i} & a_{12i} \\ a_{21i} & a_{22i} \end{bmatrix} \begin{bmatrix} \varepsilon_{dt} \\ \varepsilon_{st} \end{bmatrix} \tag{3.9}$$

where a_{11i} represents element a_{11} in matrix A_i.

The assumptions made above on the nature of the disturbances imply that while supply shocks have permanent effects of the level of output, demand shocks have only temporary effects. The cumulative effect of demand shocks on output must be zero.[7] This means that the sum of the elements a_{11} of all matrices A_i must be zero.

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[6] Doan (1992) p. 8–3.

[7] Bayoumi and Eichengreen (1992) pp. 4–5.

This model can be defined by using vector autoregression. The vector X_t is regressed on lagged values of all the elements of X, in our model on lagged values of y_t and u_t. When B represents the estimated coefficients, the VAR can be written as

$$X_t = B_1 X_{t-1} + B_2 X_{t-2} + \dots + B_n X_{t-n} + e_t \tag{3.10}$$

Its moving average representation can be written as

$$X_t = (I - B(L))^{-1} e_t \tag{3.11}$$

assuming, of course, that the AR-process is invertible, i.e. the roots of the lag-polynomial B(L) lie outside the unit circle. Write (3.11) as an infinite order moving average representation

$$X_t = C(L) e_t \tag{3.11'}$$

where $C(L) = C_0 + C_1L + C_2L^2 + \dots$.

The vector e_t is the vector of residuals or innovations from the VAR. This vector must be converted into the vector ε_t representing demand and supply shocks. Comparing (3.8) and (3.11') we see that the vector of innovations e, and the vector of original disturbances ε are related by $e = A_0\varepsilon$, and that $A_j = C_jA_0$ for all j. Thus the knowledge of A_0 allows one to recover ε from e, and similarly to obtain A_j from C_j.[8] Next we need to determine A_0 (and thus A_j). Since the moving average coefficient matrices can be estimated from the VAR, we note that, in fact, any matrix A_0 which satisfies $A_0A_0' = \Omega$ is an orthonormal transformation of the Cholesky factor S, say, of the estimated variance-covariance matrix Ω; $A_0 = ST$, where T denotes the orthonormal transformation. There are, however, restrictions on the choice of the transformation T, namely those implied by the requirement that the upper left-hand entry in $\sum C_jA_0$ be equal to zero. Thus the long-run restriction that demand disturbances be "neutral" helps us identify the orthonormal transformation T.

To summarize, we first estimate the VAR to get an estimate both of Ω and $C(1) = (I - B(1))^{-1}$. We then use the Cholesky decomposition of Ω to obtain S and calculate C(1)S. Finally, we choose an orthonormal transformation T subject to the condition that the upper left-hand entry in C(1)ST be equal to zero, and set $A_0 = ST$. The matrix operations are explained in detail in the appendix.

3.3 Description of the data

The data used in the estimations is obtained from the Bank of Finland. The time series used are the unemployment rate and the GNP from 1970 to 1992.

[8] Blanchard and Quah (1989), p. 657.

Both data are seasonally corrected and consist of quarterly observations. Before the construction of the model some general tests are performed on the data. The tests were done using PCGive, the vector autoregression and the impulse response functions were calculated using RATS.

Stationarity

To be able to construct a vector autoregressive model (VAR) one needs to make sure that the data used in the model are stationary. This is because statistics such as the t and DW statistics, and measures such as R^2 do not retain their traditional charasteristics in the presence of nonstationary data. Running regressions with such data produces spurious results.[9] Testing for nonstationarity can be done in several ways. Box and Jenkins use a casual means, inspection of the correlogram, to determine whether a series is stationary or not.

A key ingredient of their methodology is their assumption that differencing will create stationarity. A variable is said to be integrated of order d , I(d), if it must be differenced d times to be made stationary. A stationary variable is integrated of order zero.

There are several fundamental differences between a stationary and an integrated (nonstationary) series. A stationary series has a mean and there is a tendency for the series to return to that mean. An integrated series tends to wander widely. A stationary series has a finite variance, shocks are transitory, and its autocorrelations ρ_k die out as k grows. An integrated series has a variance growing over time (infinite), shocks are permanent and its autocorrelations tend to one.

For stationary data a plot of the time series against time should cross the horizontal axis frequently, and the autocorrelations should decrease over time. For nonstationary data the estimated variance should become larger as the time series is extended, it should not cross the horizontal axis often and the autocorrelations should not decrease over time.[10]

An I(1) series in its undifferenced form is constantly growing. Most macroeconomic flows and stocks that relate to population size, such as output and unemployment, are I(1). An I(2) series is growing at an ever-increasing rate. Series that are I(3) are extremely unusual. Among the few I(3) series that could be listed, one would find, for example, the money stocks or price levels in hyperinflationary economies such as interwar Germany.[11] Figure 3.1 plots the series for the GNP (in logarithms) in Finland 1970–1992, figure 3.2 plots its first difference and figure 3.3 its second difference. Examination of the figures suggests that the GNP is an I(1) series.

[9] Kennedy 1992 p. 252.

[10] Kennedy (1992) pp. 257–258.

[11] Greene (1993) p. 559.

Figure 3.1

Logarithm of GNP

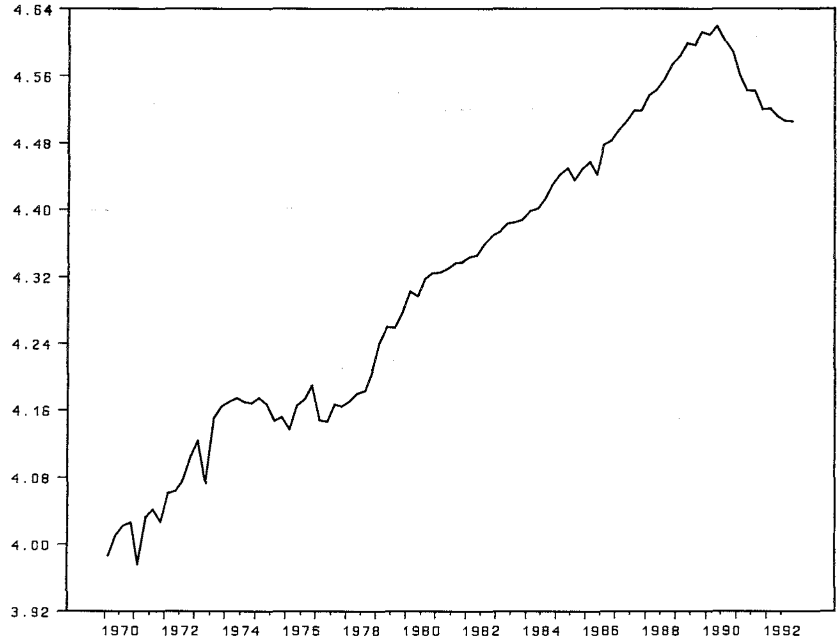


Figure 3.2

First difference of the logarithm of GNP

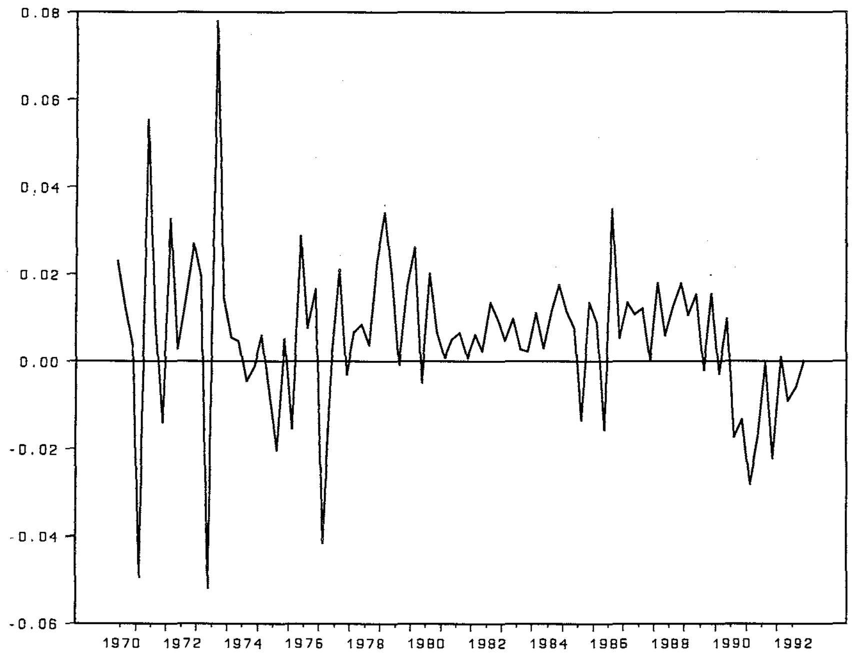


Figure 3.3 **Second difference of the logarithm of GNP**

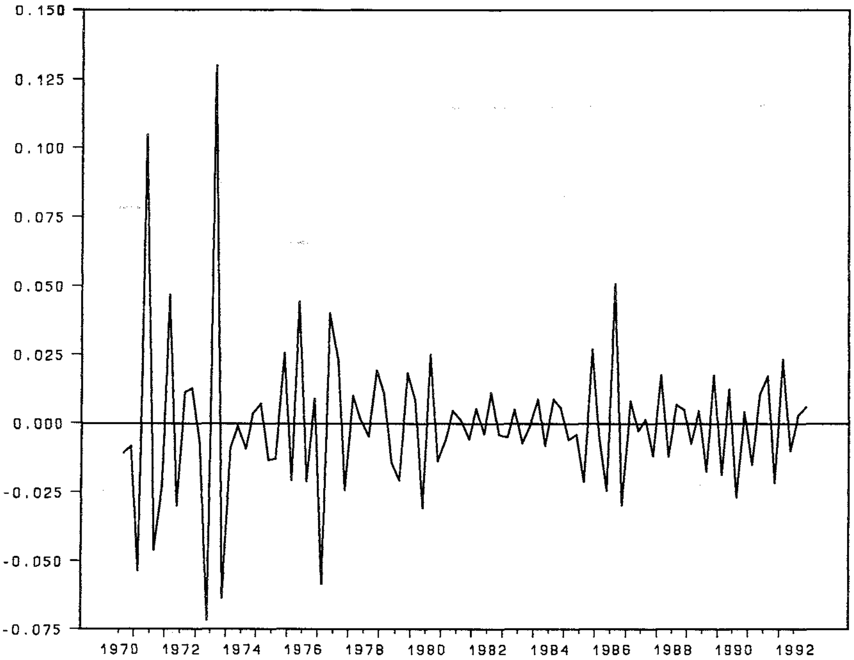
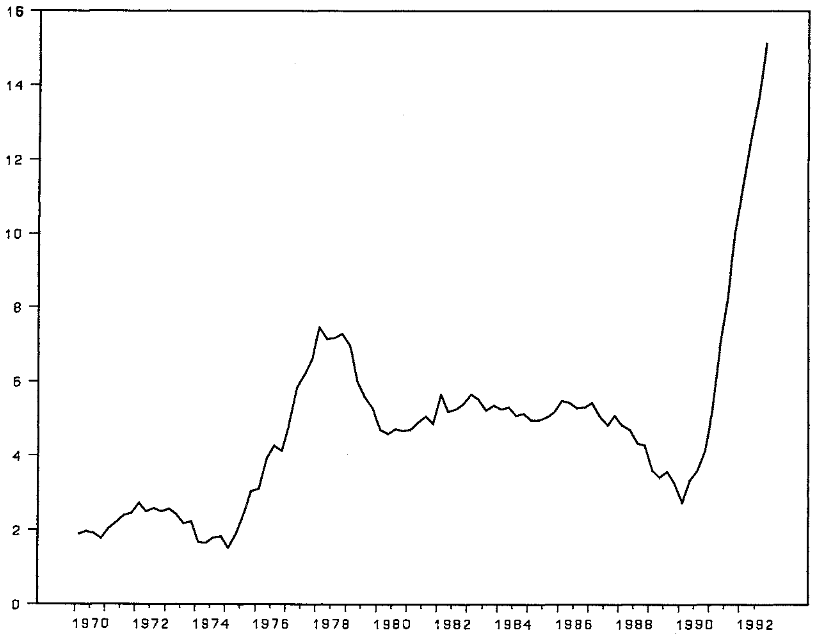


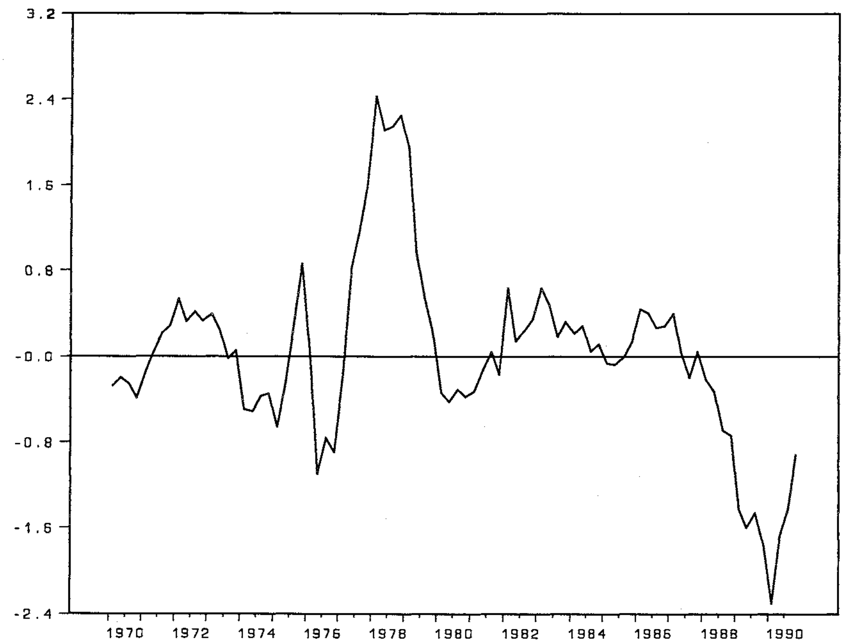
Figure 3.4 plots the unemployment rate in Finland for the period 1970–1992. Examination of figure 3.4 shows that after 1990 the unemployment rate series explodes. Construction of a VAR will become impossible if there is such a change in the rate of growth in one variable, thus we will leave years 1991 and 1992 out of this study.

Figure 3.4 **Unemployment rate**



Examination of the unemployment rate also suggest that there has been a permanent increase in the level of unemployment in 1976.[12] To capture this effect in the model we construct a new variable for unemployment. We first regress unemployment on a constant plus a dummy variable that has the value 0 before 1976 and 1 thereafter. We then subtract this result from the original unemployment series and store the residuals. Figure 3.5 shows the new series for unemployment. Examination of figure 3.5 suggests that unemployment is a stationary series.

Figure 3.5 **New unemployment**



The simplest example of an I(1) variable is a random walk. Let $y_t = y_{t-1} + \varepsilon_t$, where ε_t is a stationary error term, i.e., ε is I(0). y can be seen to be I(1) because taking its first difference, the result is $\Delta y_t = \varepsilon_t$, which is I(0). A more general form is

$$y_t = \alpha y_{t-1} + \varepsilon_t.$$

If $|\alpha| < 1$, then y is I(0), i.e., stationary, since the effect of α dies out. If $\alpha = 1$, its effect on y is fully transmitted. Then y is I(1), i.e., nonstationary. The case for $|\alpha| > 1$ is ruled out as being unreasonable because it would cause the series y_t to explode. In general, stationarity means that $E[y_t]$ is independent of time, t, and that $Var[y_t]$ is a constant, also independent of time.[13] Formal tests of

[12] There are two possible explanations for this. First, the oil crisis changed the world economic conditions in a way that increased unemployment globally, and second, though less important, there was a change in the way unemployment statistics are calculated in 1976.

[13] Greene (1993) p. 554.

stationarity are tests for $\alpha = 1$, and because of this are referred to as tests for a unit root.[14]

The test used here for testing for stationarity is a test for unit roots by Dickey and Fuller.[15] We run an OLS regression of the form

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \Sigma \Delta y_{t-i} + \varepsilon,$$

where the y_t is the logarithm of the GNP and the unemployment rate, in turns. α is a constant, t is the time trend and ε is the error term. The coefficient γ is the one of interest to us. Since the regression is run with differenced data the coefficient γ needs to be negative for the data to be stationary. If $\gamma = 0$, the data has a unit root, since differencing would have caused y_{t-1} to vanish from the left side of the equation.

Using the tables by Dickey and Fuller (in Econometrica, 1981) and looking at EQ(1) below we can see that when regressed on four lags of the differenced variable the t-value for coefficient γ for the GNP is −2.687 which is clearly below the critical value of the t-test by Dickey and Fuller −3.09 at the 5 % level. The H_0 of a unit root ($\gamma = 0$) can not be rejected. The GNP is not a stationary series.

EQ(1) Modelling ΔLgdpq by OLS First difference of GNP
The present sample is: 1971 (2) to 1990 (4)

Variable	Coefficient	Std. Error	t-value	HCSE	Part R^2	Instab
Constant	0.82006	0.30090	2.725	0.29409	0.0935	0.13
Trend	0.0014545	0.00056968	2.553	0.00057430	0.0830	0.20
Lgdpq_1	−0.20410	0.075960	**−2.687**	0.074351	0.0911	0.13
ΔLgdpq_1	−0.18889	0.11587	−1.630	0.17510	0.0356	0.05
ΔLgdpq_2	0.033703	0.12093	0.279	0.12843	0.0011	0.06
ΔLgdpq_3	0.25635	0.11837	2.166	0.12297	0.0612	0.11
ΔLgdpq_4	0.15443	0.11006	1.403	0.11292	0.0266	0.03

$R^2 = 0.223314$, $F(6,72) = 3.4503$ [0.0047], $\sigma = 0.0158931$, DW = 1.83, RSS = 0.01818649207 for 7 variables and 79 observations

Following the proposition made by Box and Jenkins we difference the GNP series and test for unit roots. EQ(2) below shows the results. The t-value of γ is −3.448 which is clearly above the critical value of −3.09. The zero hypothesis of a unit root can now be rejected. As proposed before, the first difference of the GNP is a stationary series, or, in other words, the GNP is integrated of order one.

[14] Kennedy 1992 pp. 252–253.

[15] An alternative and formal possibility would be to use Perron's test (Perron, 1989).

EQ(2) Modelling ΔΔLgdpq by OLS Second difference of GNP
The present sample is: 1971 (3) to 1990 (4)

Variable	Coefficient	Std. Error	t-value	HCSE	Part R^2	Instab
Constant	0.0096680	0.0047404	2.040	0.0056327	0.0553	0.06
Trend	−0.000031965	0.000083623	−0.382	0.00010384	0.0021	0.09
ΔLgdpq_1	−1.1271	0.32687	**−3.448**	0.39108	0.1434	0.05
ΔΔLgdpq_1	−0.11466	0.29393	−0.390	0.34503	0.0021	0.02
ΔΔLgdpq_2	−0.17237	0.25022	−0.689	0.27636	0.0066	0.14
ΔΔLgdpq_3	−0.021397	0.18742	−0.114	0.18792	0.0002	0.05
ΔΔLgdpq_4	0.018331	0.11042	0.166	0.098393	0.0004	0.02

R^2 = 0.644405, F(6,71) = 21.444 [0.0000], σ = 0.0164598, DW = 1.99, RSS = 0.01923570583 for 7 variables and 78 observations

Let us now turn to testing unemployment. EQ(3) below shows that when regressed on four lags of the differenced variable the t-statistic for the coefficient γ is −3.179. This is above the 5 % critical value of −3.09. Again the hypothesis of a unit root can be rejected. Unemployment is thus a stationary series.

EQ(3) Modelling Δue by OLS Unemployment
The present sample is: 1971 (3) to 1990 (4)

Variable	Coefficient	Std. Error	t-value	HCSE	Part R^2	Instab
Constant	0.012352	0.041925	0.295	0.044273	0.0012	0.26
ue_1	−0.19468	0.061232	**−3.179**	0.062900	0.1231	0.22
Δue_1	0.27329	0.11392	2.399	0.15516	0.0740	0.07
Δue_2	0.12711	0.11841	1.073	0.13526	0.0158	0.15
Δue_3	0.21518	0.12250	1.757	0.15802	0.0411	0.12
Δue_4	0.098865	0.12572	0.786	0.17379	0.0085	0.18

R^2 = 0.163509, F(5,72) = 2.8148 [0.0223], σ = 0.364459, DW = 1.98, RSS = 9.563811498 for 6 variables and 78 observations

The Box-Pierce Q-statistic

The Box-Pierce Q-statistic is used for testing if the residuals are white noise. The Q-statistic is defined as

$$Q = T\sum_{\tau=1}^{P} \tilde{r}_\tau^2$$

where r_τ is the τth sample autocorrelation in the residuals. If the model is correctly specified, Q has a χ^2 distribution with P−p−q degrees of freedom. Here P is equal to 8 and p and q to zero. High values of Q lead to a rejection of the hypothesis of approximately random residuals.[16] The 5 % critical value of $\chi^2(8) = 15.507$. The Q-statistics are shown above each correlogram and they are calculated: N*(Sum of squared Residual Autocorrelations).

Residual correlogram for GNP

78*(Sum of 8 squared Residual Autocorrelations) = **8.06 Q-statistic**

```
 -1                        0                         1
lag
 1  |........................|........................|   -0.012609
 2  |........................|*.......................|    0.039942
 3  |.......................*|........................|   -0.089113
 4  |........................|***.....................|    0.098193
 5  |........................|*.......................|    0.055525
 6  |........................|***.....................|    0.1184
 7  |.....................***|........................|   -0.1639
 8  |....................****|........................|   -0.20008
```

Residual correlogram for unemployment

78*(Sum of 8 squared Residual Autocorrelations) = **2.118 Q-statistic**

```
 -1                        0                         1
lag
 1  |........................|........................|    0.0068605
 2  |........................|........................|    0.0075426
 3  |........................|........................|   -0.010028
 4  |........................|........................|    0.016033
 5  |.......................*|........................|   -0.078055
 6  |........................|**......................|    0.071106
 7  |........................|*.......................|    0.042042
 8  |......................**|........................|   -0.11737
```

The Q-statistic of the GNP has the value of 8.06 which is clearly below the 5 % critical value of $\chi^2(8) = 15.507$. The zero hypothesis of approximately random residuals cannot be rejected. The Q statistic for the unemployment has the value of 2.118 which is also below the 5 % critical value. Thus the zero hypothesis is not rejected, residuals are random.

3.4 Empirical results

We now turn to the results of the empirical analysis. The results are first presented for the period 1970–1990 and then for two sub-periods, 1970–1983 and 1984–1990, respectively. The first sub-period is treated as the period of zero capital mobility and the second as the period of increased capital mobility.

The reason for comparing two sub-periods is to find out whether liberalization of capital markets had an effect on the transmission of disturbances or not. From table 2.2 can be seen that from the point of view of private companies the largest liberalization measures were taken in 1985. However, we chose to use year the 1984 as the breaking point. Having only six years available for the last period of the study would have created problems in

[16] Harvey 1981 p. 30.

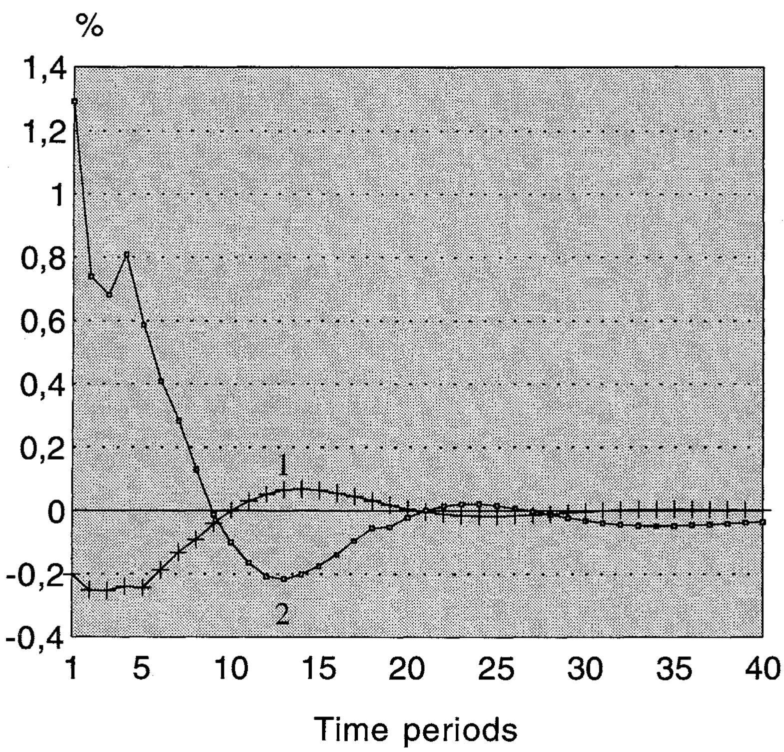
empirical estimations because of the loss of degrees of freedom. One can also argue that capital flows had sufficiently increased by 1984 to be considered non-zero. For the purpose of this study the assumption of perfect capital mobility is not necessary and thus year 1984 was chosen as the breaking point between the two sub-periods.

There is only one restriction on the impulse response functions: demand shocks do not have permanent effects on output. In contrast, there are no restrictions on the effects of demand disturbances on unemployment nor on the effects of demand and supply disturbances on both output and unemployment.

Responses to shocks 1970–1990

Figure 3.6 shows the graph of the responses of output growth and unemployment to demand shocks. Time periods measure time in quarters of a year.

Figure 3.6 **Responses to demand shocks 1970–1990**



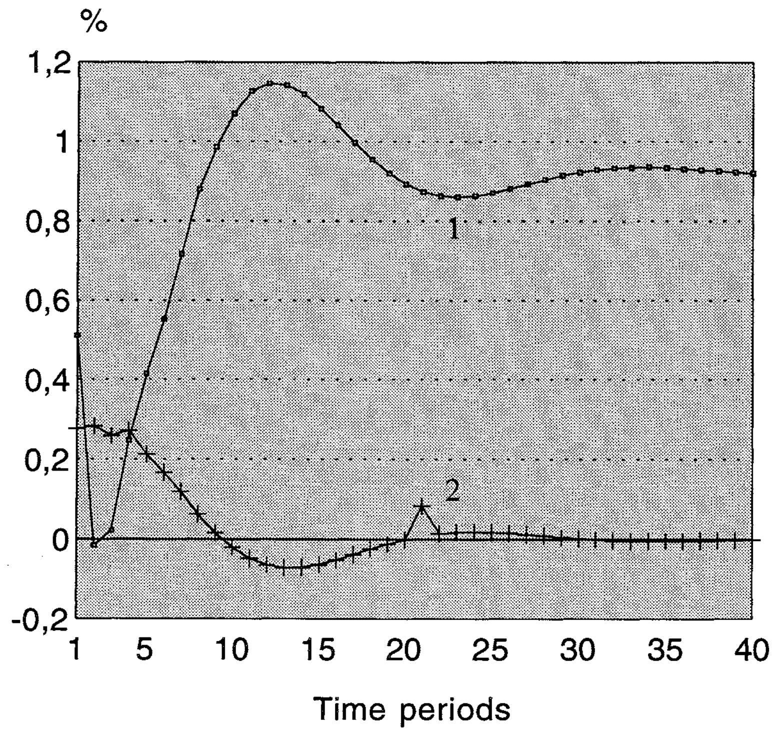
1 Unemployment responses
2 Output responses

A positive demand shock of one percent at period 0 increases the growth rate of output by 1.3 % in period 1. The effect then slowly dies out during the first two years (until period 8). The net effect of a positive demand shock sums to zero, as is restricted by the model. Thus demand shocks do not have permanent effects on output growth, the path of responses to positive demand shocks stabilizes around zero after approximately five years.

Consider next unemployment responses. A positive demand shock decreases unemployment by approximately 0.2 %. During the first year unemployment stabilizes at this level but then starts to rise and finally stabilizes again at its original level. This effect is in accordance with Okun's law, which states, that increases in output decrease umemployment by a ratio of 3:1. An increase in output of 0.6 % (at period 2) has decreased unemployment by 0.2 %, a ratio of 3:1.

Responses to supply shocks have a different pattern. Figure 3.7 graphs output and unemployment responses to a positive supply shock.

Figure 3.7 **Responses to supply shocks 1970–1990**



1 Output responses
2 Unemployment responses

Examining figure 3.7, one can see that output increases at first, then immediately decreases to the zero-level and then starts to increase again. Full effect is reached after approximately three years at a 1.2 % increase in output. The increase is permanent, it stabilizes at a level of 0.9 % after 5 years.

The effect of the sudden decrease in output after the first period is interesting. An explanation for this effect can be found. Consider a new technological innovation in the economy. At first output increases when the new innovation is introduced to the markets. What then happens, is that productivity increases, and momentarily output decreases as the producers using the old technology get out of business. As new producers take their place, output starts to increase again.

Consider next unemployment responses. The first effect is an increase in unemployment for a short time. Unemployment then starts to decrease and finally stabilizes around its natural level. After approximately three years (12 periods), at the same time that output has reached its peak, unemployment is at its lowest level.

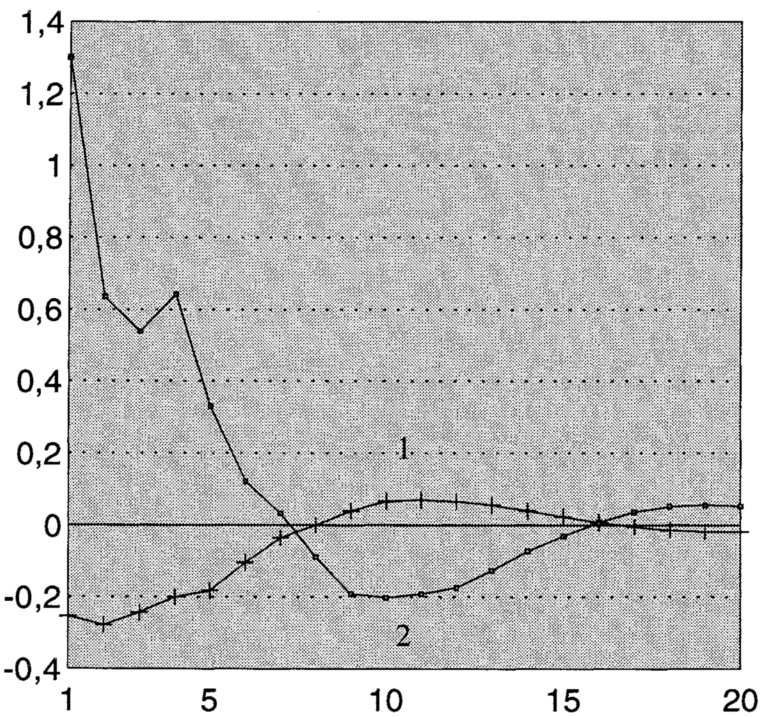
Following the story of the new techonological innovation in the economy at period 0, the increase in productivity in one sector (new technology sector) increases unemployment in an another sector (old technology sector). When the new producers start producing at an increasing pace, unemployment decreases accordingly. Thus it is not a surprise that output and unemployment reach their peaks at the same moment.

Responses to shocks 1970–1983

The first liberalization measures were taken in 1980, but capital mobility did not increase considerably during the first few years. For the purpose of this study the period 1970–1983 can be seen as the **low capital mobility period**.

The effects of the shocks are similar to the ones for the whole period 1970–1990, described above. Especially responses to demand shocks follow the same pattern. Figure 3.8 graphs the responses to demand shocks.

Figure 3.8 **Responses to demand shocks 1970–1983**



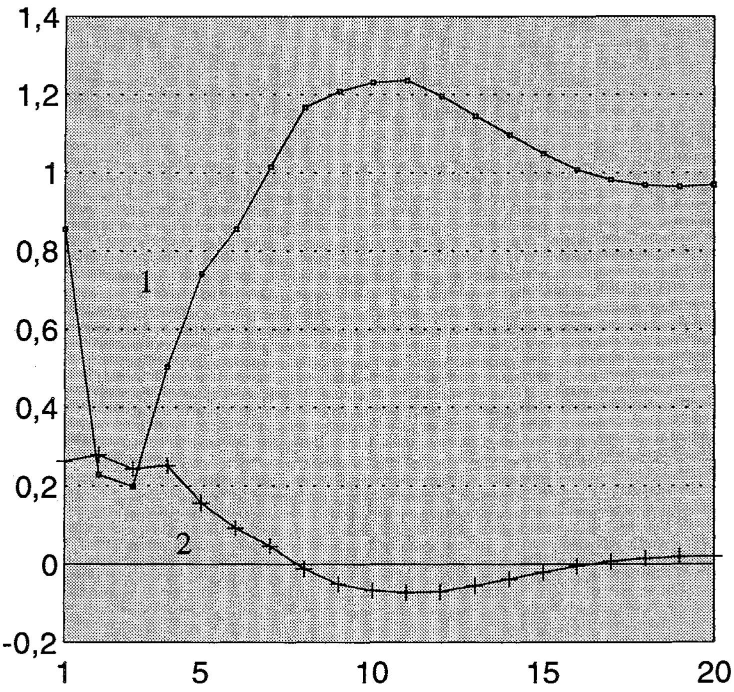
1 Unemployment responses
2 Output responses

A one percent positive demand shock at period 0 increases output 1.3 % in period 1. The effect of the shock then slowly dies out. Stabilization is slightly faster in this sub-period than in the whole period estimated.

Unemployment decreases at first by 0.2 % and then stabilizes around zero after approximately four years. The time needed for the stabilization of unemployment in the whole period was five years. One should bear in mind that in the underlying model, demand and supply shocks are identified so that their long run effects on unemployment are non-existent.

Responses to supply shocks in this sub-period are somewhat different than in the whole period. Figure 4.9 graphs output and unemployment responses to a positive supply shock in period 0.

Figure 3.9 **Responses to supply shocks 1970–1983**



1 Output responses
2 Unemployment responses

The output response to a supply shock is larger in this sub-period than in the whole period, an increase of 0.9 % compared with an increase of 0.5 %. The following decrease in output is in turn smaller, output does not fall back to its original level, not even momentarily. Stabilization to 1 % is reached after four years, after a peak of 1.2 % increase in output.

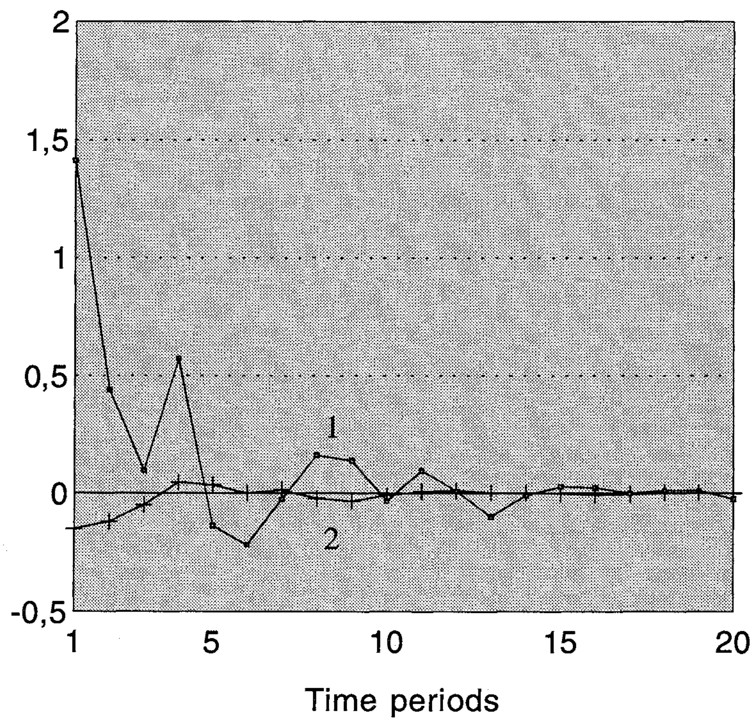
The path followed by unemployment is again the same as previously, only stabilization happens a year earlier, after four years. Again, output and unemployment stabilize at their long run levels at the same time.

Responses to shocks 1984–1990

In this period capital mobility is considered non-zero. Even though complete capital mobility does not prevail in this sub-period, for the purpose of this study the assumption of **increased capital mobility** is sufficient.

When capital mobility increases responses to demand shocks die out faster. Both output and unemployment responses stabilize around zero after one year. The time needed for the stabilization in the period of low capital mobility was twice as long. Figure 3.10 graphs responses to demand shocks.

Figure 3.10 **Responses to demand shocks 1984–1990**



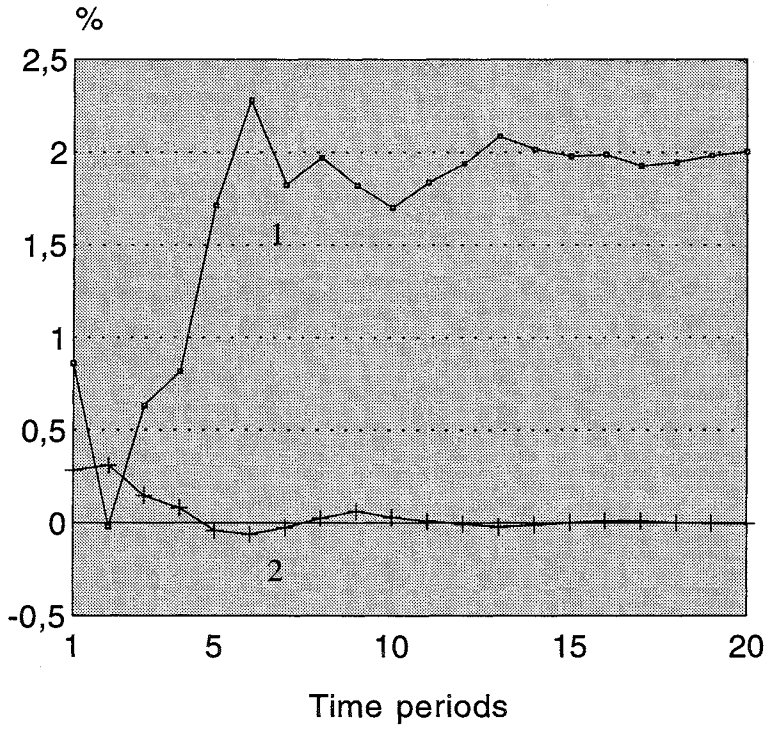
1 Output responses
2 Unemployment responses

As will be shown in the next chapter, theory suggests that the liberalization of capital movements increases the slope of the aggregate demand curve making the curve flatter. Thus the effect of supply shocks on the economy becomes larger. Examination of figure 3.11 below tells us that this has been the case also in Finland.

Short run output responses are similar in magnitude to the ones observed in the low capital mobility period. Long run output responses are larger and stabilize after approximately two years to a level of 2 %.

The only change in unemployment responses is that they die out as early as during the first year after the shock. The time needed for this adjustment was twice as long in the period of low capital mobility.

Figure 3.11 **Responses to supply shocks 1984–1990**



1 Output responses
2 Unemployment responses

4 Theoretical framework

The model used to study the effect of disturbances on the economy restricted the number of disturbances to two and called them conveniently demand and supply disturbances. The simplest theory that provides us a framework for the transmission of these disturbances on the economy is actually the theory of aggregate demand and supply.

The equation for money supply in the fixed price level IS–LM model says that money supply is equal to the real money stock.[17] When the price level is allowed to change the real money stock M/P varies accordingly. This is the point of entry of the price level to the IS–LM system.

As the price level falls, the real value of the nominal money stock increases and the LM curve shifts to the right. Aggregate demand and output increase. The relationship between aggregate demand and the price level can be graphed in (Y,P) space, the aggregate demand curve is then downward sloping.

The negative slope of the aggregate demand curve derives from the "Keynes effect": the higher the price level the lower the value of the nominal money stock, requiring a higher interest rate to preserve equilibrium in the money market, which in turn induces a lower level of interest-sensitive

[17] Actually, in the equation money supply is equal to the nominal money stock which in effect is equal to the real money stock since the price level is fixed and normalized to unity.

expenditure. Thus is it clear that the slope of the aggregate demand curve depends on all the structural parameters of the IS and LM functions.[18]

The position of the aggregate demand curve is determined by the levels of autonomous components of expenditure and the nominal money stock. These are therefore the variables that will change the level of aggregate demand for any given price level. Consider an increase in government expenditure (or in any autonomous component of expenditure) that shifts the IS curve up to the right and increases aggregate demand from Y to Y'. In (Y,P) space, the aggregate demand curve shifts to the right by the horizontal distance YY'. Increases in the money stock have a similar effect.

On the supply side of the economy firms maximize their profits and employ labor up to a point where the real wage W/P equals the marginal product of labor. When the price level rises, real wage falls, more labor is employed and thus output increases. In (Y,P) space, aggregate supply is an upward sloping function until the full employment level. It can be argued that after the full-employment level the long-run aggregate supply schedule is vertical.

When there is a positive **supply shock** in the economy (a favourable technology that permanently raises potential output, for instance) the short run supply curve (SRAS) shifts to the right. Output increases and prices fall, the fall in prices increases productivity. This increase in productivity increases output further and the long rung aggregate supply curve (LRAS) shifts also to the right. The short- and long-run aggregate supply curves shift to the right by the same amount, displacing the term equilibrium. Thus the output increasing effect of a positive supply shock is permanent and the price level is lower. The magnitude of the increase in output is equal to the magnitude of the shock, this can be seen on the graph: output increases by the amount YY'' which is exactly equal to the horizontal shift of the LRAS. The results of the empirical study are in accordance with the theory, the effects of a supply shock are permanent.

A positive **demand shock** shifts the demand curve up to the right causing output and prices to increase. In the long run output returns to its original level as determined by the LRAS. Equilibrium is reached at a higher price level. In the empirical study the effects of demand shocks on output were restricted and consequently it is no surprise that the results are in accordance with thc theory. Figure 4.1 and 4.2 below graph the effects of supply and demand disturbances.

[18] Stevenson et al. (1988) p. 14.

Figure 4.1 **Effects of supply disturbances**

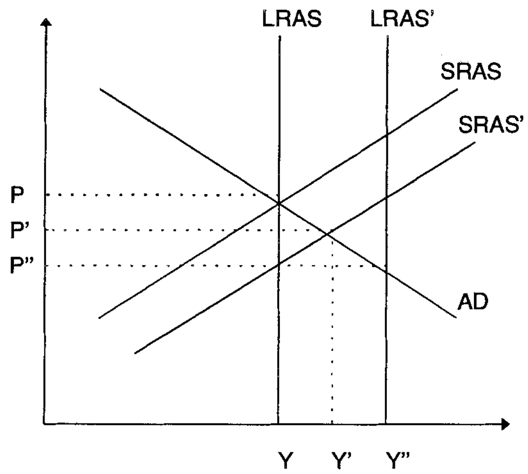
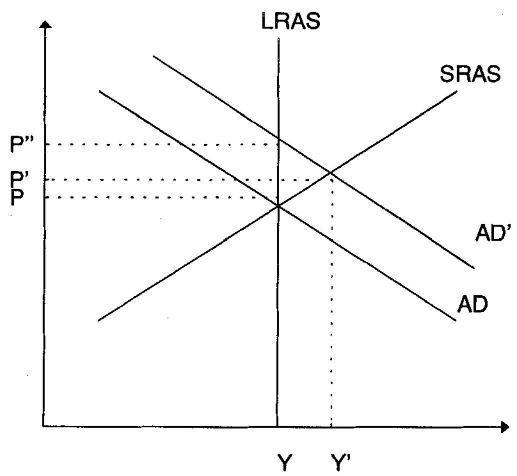


Figure 4.2 **Effects of demand disturbances**



Source: Bayoumi and Eichengreen (1992) p. 3.

Aggregate demand in the open economy

The slope of the open economy aggregate demand curve depends, among other things, on the degree of capital mobility. If, as typically observed, the liberalization of capital movements goes with deregulation of domestic financial markets, the slope of the aggregate demand curve should increase, i.e. the demand curve should become flatter.[19] When the aggregate demand curve is flatter the effects of a positive supply shock on output are larger. This effect was clearly the result of the empirical study. The slope of the aggregate demand curve can be defined using the Mundell-Fleming model.

[19] This is due to decreased marginal propensity to consume.

The Slope of the AD-curve: the Mundell-Fleming Model

The Mundell–Fleming model is a model of the open economy. The country examined is assumed to be small and to produce and export a relatively specialized good. This means that in the market for the exported good the country is a price-maker but in the market for imports the country is a price-taker. The imported good competes in the domestic markets in consumption but not in production. The world real income and price level are given.

Following Stevenson et al. (1988) the starting point of the model is the determination of the current account in the standard fix-price Keynesian model. Net property income from abroad and unilateral transfers are ignored, so that the current account is equal to the trade balance. Net exports are assumed to be a function of domestic real income y (imports are a positive function of income) and of competitiveness. Competitiveness is defined as eP^*/P, where P^* and P are the world and domestic price levels respectively, and e is the domestic currency price of foreign exchange. The current account equation may be written as:

$$CA = ca(y, eP^*/P) \qquad \frac{\partial ca}{\partial y} < 0, \ \frac{\partial ca}{\partial (eP^*/P)} > 0 \tag{4.1}$$

Assuming that P and P^* are fixed, the equation can be rewritten as CA = ca(y,e). The fact that $\partial ca/\partial y$ is negative is due to the marginal propensity to import. When income increases, imports increase (by some fraction of the increase in income) and the trade balance deteriorates. The positive value of $\partial ca/\partial e$ assumes that a rise in the real exchange rate (depreciation or devaluation of the domestic currency) generates an increase in exports and decrease in imports.

The capital account K is a function of the differential between the domestic interest rate r and the world interest rate r^*. The higher the domestic interest rate is relative to the world rate, the more attractive are domestic assets and therefore the greater is the inflow of capital, K.[20]

$$K = k(r - r^*) \qquad \frac{\partial k}{\partial (r - r^*)} > 0 \tag{4.2}$$

The overall balance of payments equation can be written as:

$$BP = CA + K = ca(y,e) + k(r - r^*) \tag{4.3}$$

The Mundell–Fleming model essentially consists of an integration of the balance of payments equation (4.3) into a standard fix-price IS–LM model. At

[20] This specification of the capital account relates interest differentials to capital flows. It can be argued that a given international structure of interest rates will be associated with a given distribution of asset stocks among countries, and that only changes in interest rates will generate capital flows, as stocks are adjusted.

every point on the BP curve the balance of payments is in equilibrium. The curve is upward sloping because the capital account surplus brought about by higher domestic interest rates offsets the current account deficit generated by higher income levels. The two limiting cases of capital mobility are those of perfect capital mobility (horizontal BP) and zero capital mobility (vertical BP). Points above the BP curve represent combinations of y and r that generate balance of payments surpluses and points below the BP curve are associated with deficits.

Effects of unanticipated shocks under zero capital mobility

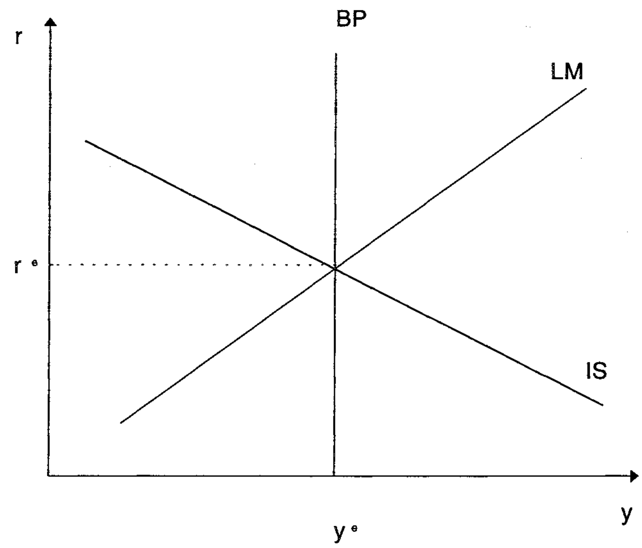
Let us now consider the effects of unanticipated shocks. The exchange rate is fixed throughout the analysis. Capital movements are non-existant, meaning that the BP curve is vertical. The domestic interest rate can be different from the world interest rate since capital cannot flow between different financial markets to equate interest rates. Figure 4.3 below shows equilibrium in the model under zero capital mobility.

A positive shock affecting the IS curve (e.g., expansionary fiscal policy or increased export demand) shifts the IS curve up to the right. Both output and interest rate rise above their original levels. The balance of payments (current account) is now in deficit. This deficit needs to be financed by using foreign exchange reserves and thus money supply decreases and the LM curve shifts to the left up to a point where internal and external equilibria are reached. The interest rate increases further but output returns to its original level.

A negative shock affecting the IS curve shifts it to the left creating a balance of payments surplus (current account surplus due to decreased import demand). The money stock then increases and the LM curve shifts to the right. The interest rate falls below its original level but there is no change in output.

A positive monetary shock (e.g., expansionary monetary policy) shifts the LM curve down to the right. Output increases and creates a deficit in the current account (imports increase). Foreign exchange reserves are again used to finance the deficit and this reduces the existing money stock. The LM curve shifts back to its original position. There is no effect on output or the interest rate. The same mechanism is at work (in the opposite direction) when there is **a negative shock on the LM curve**. The net outcome again is no change in output or the interest rate.

Figure 4.3 **Equilibrium in the Mundell–Fleming model under zero capital mobility**



Effects of unanticipated shocks under perfect capital mobility

When capital movements are completely free, the BP curve is horizontal. The domestic interest rate is always equal to the world interest rate since capital movements equate returns in different financial markets immediately. Figure 4.4 below shows equilibrium in the model under perfect capital mobility.

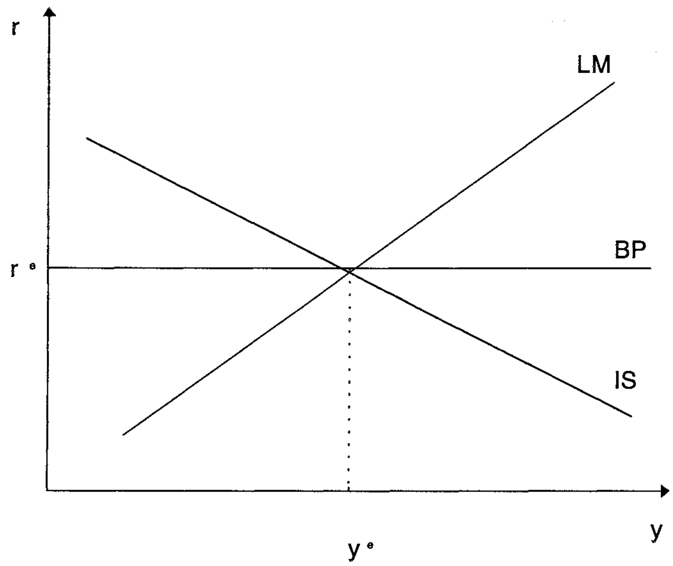
A positive real shock shifts the IS curve up to the right. Capital inflows attracted by the higher domestic interest rate lead to a surplus in the balance of payments (capital account) and increase the money stock. Thus the LM curve shifts to the right until the domestic interest rate is again equal to the world interest rate and both internal and external equilibria are reached at a higher level of output.

A negative shock on the IS curve shifts it to the left. The interest rate falls below the world level and capital flows out to higher returns markets creating a balance of payments deficit. The money stock is reduced and the LM curve shifts to the left. Output falls even further and the interest rate rises to its original level.

A positive monetary shock shifts the LM curve to the right. The interest rate is below the world interest rate and capital flows out of the country creating a balance of payments deficit. Foreign exchange reserves are used to finance the deficit and thus money supply decreases. The LM curve shifts back to its original level. There is no change in domestic output nor the interest rate.

A negative monetary shock shifts the LM curve to the left. The interest rate increases above the equilibrium level. Capital flows in attracted by the higher returns, this immediately increases money supply and the LM curve shifts back to its original position.

Figure 4.4 **Equilibrium in the Mundell–Fleming model under perfect capital mobility**



5 Concluding remarks

The purpose of this study was to analyze the dynamic effects of demand and supply disturbances on the economy. Secondly, the effects of liberalization of capital movements on the transmission of demand and supply disturbances to the Finnish economy were studied.

Theory suggests that increased capital mobility increases the magnitude of output responses to supply shocks in the long run. The results of the empirical study are in accordance with the theory. Comparison of two sub-periods, 1970–1983 and 1984–1990 proved that output responses to supply shocks are larger during the liberalized period.

Estimations were done using a vector autoregressive model and the corresponding impulse response functions discovered from this process. The data used were the GNP and unemployment rate in Finland during 1970–1990. Both data were seasonally corrected and consisted of quarterly observations.

Because of the sudden increase in unemployment after 1990, the estimations had to be restricted to 1970–1990. It would have been interesting to analyze whether the responses to shocks have changed during the present period of the seemingly ever-increasing unemployment. A further interesting question is whether the change in the exchange rate regime in 1992 has altered the dynamic effects of disturbances on the economy. However, these questions are beyond the scope of this study and are left for further research.

References

Bayoumi, T., Eichengreen, B. (1992) "Macroeconomic Adjustment Under Bretton Woods and the Post-Bretton-Woods Float: an Impulse-Response Analysis", NBER Working Paper No. 4169, September 1992.

Blanchard, O.J., Quah, D. (1989) "The Dynamic Effects of Aggregate Demand and Supply Disturbances", The American Economic Review, vol. 79 no. 4, September 1989.

Dickey, D., Fuller, W. (1981) "Likelihood Ratio Statistics for Autoregressive Time Series With a Unit Root", Econometrica, Vol 49, No. 4, July 1981.

Doan, T.A. (1992) RATS User's Manual Version 4, Estima, USA.

Greene, W.H. (1993) Econometric Analysis, 2nd ed., New York.

Harvey, A.C. (1981) The Econometric Analysis of Time Series, Philip Allan Publishers Ltd., Oxford.

IMF Annual Report on Exchange Arrangements and Exchange Restrictions 1981–1992.

Kennedy, P. (1992) A Guide to Econometrics, 3rd ed., The MIT Press, Cambridge, Massachusetts.

Nyberg, P. (1992) "Foreign Exchange Deregulation in Finland: Principles, Practice and Consequences", Bank of Finland Working Paper 3/92.

OECD Exchange Control Policy, 1993.

Perron, P. (1989) "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", Econometrica, Vol. 57, No. 6, November 1989.

Stevenson, A., Muscatelli, V., Gregory, M. (1988) Macroeconomic Theory and Stabilisation Policy, Philip Allan, Great Britain.

Appendix

The matrix operations used in the methodology are described in detail in this appendix. The output and the commands are presented as they are in RATS 4.0. The actual figures are from the estimations of the period 1970–1983.

Following chapter 3.2, the VAR is first estimated for X_t, a vector of variables y_t and u_t. The resulting variance-covariance matrix Ω is

```
declare symmetric Ω
compute Ω = ||0.000242064|–0.00107,0.13355||
write Ω
2.42064e-004
–0.00107          0.13355
```

The Cholesky decomposition of Ω, which we denote by S, is

```
compute S = %decomp(Ω)
write S
    0.01556       0.00000
    –0.06877      0.35892
```

From the VAR regression coefficients we then calculate the matrix I–B(1) denoted here by b0.

```
declare rect b0
compute b0 = ||2.1116206,–0.012825|0.6415153,0.2512039||
write b0
    2.11162       –0.01282
    0.64152       0.25120
```

b0 must then be inverted to a moving average representation to get $C(1) = (I-B(1))^{-1}$ as follows:

```
compute C(1) = inv(b0)
write C(1)
    0.46634       0.02381
    –1.19091      3.92003
```

We then use the Cholesky decomposition of Ω, S, and multiply C(1) by it to calculate C(1)S

```
compute C(1)S = C(1)*S
write C(1)S
    0.00562       0.00855
    –0.28812      1.40696
```

The orthonomal transformation is restricted by the requirement that the upper left-hand entry in $\sum C_j A_0$ be equal to zero. This restriction helps us identify the orthonormal transformation T which is calculated from C(1)S.

```
declare rect T
compute T = ||0.8356413,0.5492753|–0.5492753,0.8356413||
write T
    0.83564      0.54928
   –0.54928      0.83564
```

We then multiply C(1)S by T and get a matrix in which the upper left-hand entry is equal to zero just as intended. This proves that the orthonormal transformation is the correct one and that it can be used in the next step.

```
compute C(1)ST = C(1)S*T
write C(1)ST
    1.02472e-006        0.01023
   –1.01357             1.01745
```

The last step of the procedure is to calculate A_0 which allows us to recover the impulse response functions needed. As presented in chapter 3.2, A_0 is simply equal to the Cholesky decomposition of the original variance-covariance matrix multiplied by the identified orthonormal transformation of C(1)S.

```
compute A0 = S*T
write A0
    0.01300      0.00855
   –0.25461      0.26215
```

It is easy to verify the reliability of A_0 by simple matrix operations. Chapter 3.2 stated that any matrix A_0 which satisfies $A_0A_0' = \Omega$ is an orthonormal transformation of the Cholesky factor S of the variance-covariance matrix Ω. To verify this we simply check whether A_0A_0' is equal to Ω.

```
compute A0' = tr(A0)
write A0'
    0.01300      0.13967
    0.00855     –0.33770

compute g2 = A0*A0'
write g2
    2.42064e-004        –0.00107
   –0.00107              0.13355
```

And luckily, we find that indeed, g2 is equal to Ω and the calculations are reliable.

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