Transmission of Business Fluctuations between Large and Small Economies: An Application to the EU15 and Jordan

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Abstract:

Why is there a negative correlation between business cycles in Jordan and the EU15? This paper explores the hypothesis that TFP increases in Europe spill over to Jordan only if embodied in FDI, but that European TFP growth negatively affects the Jordanian economy through higher world interest rates and thus lowers Tobin's *q*. A dynamic stochastic equilibrium business cycle model is used to quantify the importance of this transmission channel. Simulations with observed exogenous impulses suggest a reasonably good performance of the model economy and a frequency domain analysis suggests that this is particularly true for business cycle frequencies. However, further research is necessary in order to improve the implications for investment behavior.

Keywords: Euro-Mediterranean partnership, business cycle transmission, DSGE, Watson test.

JEL: E32, O11

1. Introduction

Recent (and not so recent) business cycle research has come up with rather robust conclusions on synchronization and transmission of business fluctuations between open economies. Extensive work by Backus and Kehoe (1992) suggests that international output correlations are positive or zero for major industrialised countries, and Artis and Zhang (1995) present strong evidence of positive output correlations for most Western European countries with both the German and the US cycle. In equilibrium business cycle theory, Backus, Kehoe, and Kydland (1992) for instance have presented a model with positive cross-country consumption correlations and insignificant output correlations, while Zimmermann (1997) specifies a model for heterogenous countries which yields positive output correlations much in line with what one would expect. By and large, the central finding seems to be that sufficiently strong channels exist by which impulses from one country spill over to other countries and that this shock transmission leads to more or less synchronized international fluctuations.

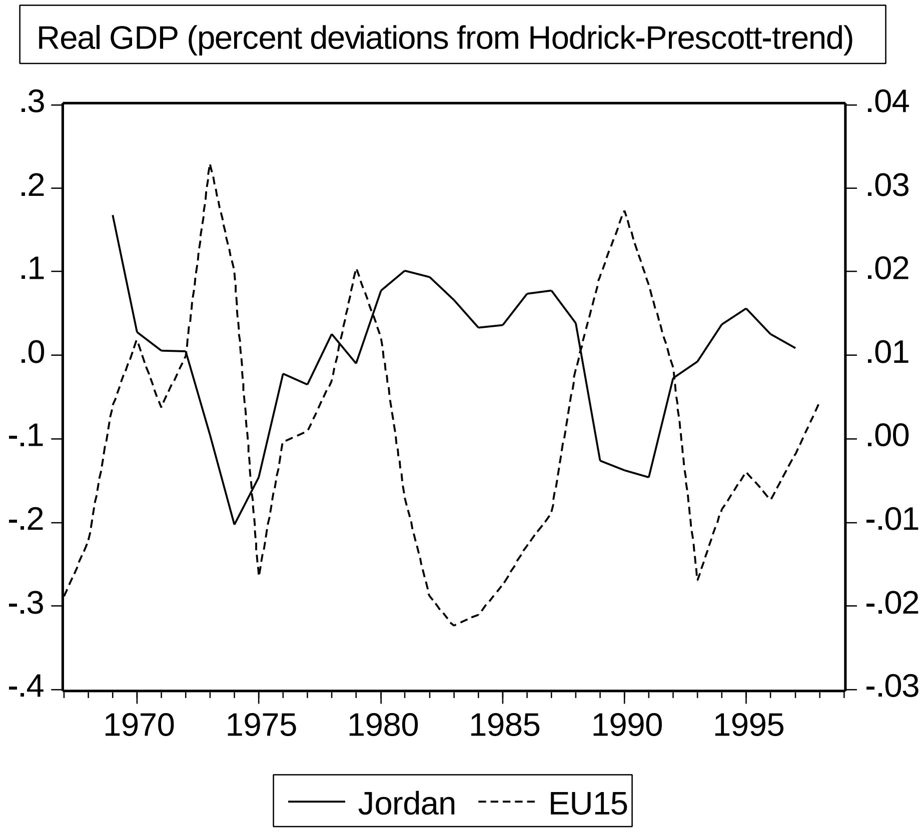
The underlying assumption of these results is that of „large“ economies whose economic performances have non-negligible impact on the performance of other economies. The case of business cycle transmission between a „large“ and a „small“ economy has received less attention in the literature, perhaps because by definition the transmission in this case is one-directional and thus only the small economy needs to be modeled – the large economy can be reduced to a shock-generator. As such, transmission of business cycles involves basically the study of small open economies subject to external business cycle shocks which affect the country‘s balance of payments.

The issue is nevertheless interesting, since some of the empirical regularities for small countries are at odds with conventional wisdom. For Jordan, for instance, business cylces are *negatively* correlated with business cycles in the EU15[1]. This is illustrated in Figure 1, where real GDP (expressed as percentage deviations from a Hodrick-Prescott (HP) trend) is displayed for a period of more than thirty years (1967-1998)[2].

[1] I focus on the EU rather than the US as the „large“ country both because of „gravity“ considerations and because the EU and Jordan have agreed on a far-reaching framework of integration under the Mediterranean Initiative.

[2] The Jordanian Department of Statistics introduced a change in the system of National Accounts in 1998. Since then, the national accounts are expressed in basic price rather than at factor costs, such that more recent Jordanian data are incompatible with the series I used in this paper.

Figure 1



The correlation is -.58 and the European GDP is, in fact, highly significant in an autoregression of the Jordanian GDP. Again, variables are HP-detrended and t-statistics are given in parentheses:

$$\hat{y}_t^{Jor} = -0.00 + 0.54\ \hat{y}_{t-1}^{Jor} - 2.22\ \hat{y}_t^{EU} \qquad \bar{R}^2 = 0.61 \quad DW = 1.68$$
$$(-0.30) \quad (4.65) \qquad (-3.38)$$

While the empirical evidence for a negative spillover effect from the EU15 to Jordan is fairly robust, the economic interpretation is unclear. Transmission channels focusing on aggregate foreign demand are certainly not a promising candidate, since trade impulses would lead to a positive correlation between fluctuations in the EU15 and Jordan. Besides, the volume of trade between Jordan and the EU15 is rather small: The EU accounts for just about 7% of Jordanian exports, much less than in many other Middle Eastern countries. But a positive correlation between outputs would also obtain for a standard treatment of the most popular aggregate supply shocks, i. e. impulses to technology. If, as it is typically assumed in modern equilibrium business cycle models, technological innovations induce business cycles, then the observed phenomenon of a negative correlation requires an assumption on asymmetric effects of technological impulses.

The technological assumption explored in this paper thus departs from the neoclassical benchmark of instantaneous, free dissemination of advances in technological knowledge. Rather, I assume that technological innovations always originate in the developed, industrialized countries, i. e. the EU15 for the purpose of this study, and that the sole transmission channel for technology shocks are foreign direct investments, which embody new technological knowledge. Thus, the level of technology in the developing country is not directly affected by technological innovations in the EU15, but relies on the willingness of foreign investors to make the knowledge available via FDI.

Under this assumption, (and so long as FDI inflow is constant), technology-driven business fluctuations will lead to a negative correlation as observed in the data. This is so because positive technology shocks in the EU15 increase the marginal product of capital. Hence an economic expansion goes along with an increase in the long-run real interest rate in the EU15. By the large country-assumption, this increase is transmitted to world capital markets. Since Jordan is modeled as a small open economy with capital mobility, the expansion in Europe leads to a rise in Jordanian interest rates and hence decreases Tobin's *q*. But, with constant FDI, the increase in interest rates is not matched by a similar increase in Jordan's total factor productivity (TFP). Thus investment decreases, negatively affecting aggregate demand. This effect is reinforced by higher interest obligations on foreign debt if the small country (as it is the case for Jordan) is a net debtor. Moreover, the fall in investment has a negative impact on future factor inputs, such that the supply effect is also negative.

A simple regression shows that this way of economic reasoning may indeed be appropriate. (Note that the reasoning assumed constant FDI only for demonstrative purposes – FDI will vary in the actual analysis (and thus increase Jordanian TFP) and will, in fact, have some explanatory power). Regressing the (HP-detrended) Jordanian GDP on its own past, a European long-run interest rate, and the net flow of FDI into Jordan yields the following results (sample 1972-1996):

$$\underset{}{\hat{y}_t^{Jor}} = \underset{(2.24)}{0.15} + \underset{(3.08)}{0.46}\ \hat{y}_{t-1}^{Jor} - \underset{(-2.58)}{2.36}\ r_t^{EU} + \underset{(2.73)}{0.03}\ fdi_t^{Jor} \qquad \bar{R}^2 = 0.61 \quad DW = 1.53$$

Here, r_t^{EU} is the German government bond rate (since Germany was dominating EU capital markets prior to introduction of the EMU), and fdi_t^{Jor} is the net inflow of FDI into Jordan relative to its sample mean. All regressors are significant well below the 5% level and, as measured by $\bar{R}^2$, the explanatory power of the interest rate and of FDI seems to be exactly the same as the explanatory power of EU15 GDP.

While the above regression may be suggestive, it is merely descriptive and lacks sound economic foundations. In particular, effects of rising world interest rates are not confined to lowering Tobin's *q*. For instance, the intertemporal price of consumption decreases, i. e. savings and thus domestic capital supply increase. Simultaneously, labor supply will increase, if demand for leisure falls along with consumption, and hence there may be a larger supply of both production inputs in response to rising world interest rates. Hence the net effect on domestic output is far from clear.

The strategy taken in this paper consists of specifying a dynamic stochastic general equilibrium (DSGE) model for the Jordanian economy. The model is essentially due to Correia, Neves and Rebelo (CNR) (1995), but unlike their analysis, the focus on aggregate technology shocks is different. Domestically, as explained above, technology is constant unless being altered by FDI. The main impulse, by contrast, stems from exogenous dynamics of foreign interest rates, and thus from technology shocks which are perhaps confined to the foreign country. In addition, shocks to transfers and to government expenditures are taken into account. Unlike total factor productivity, all these shocks are observable. The corresponding exogenous processes are estimated from time series data and then plugged into the model in order to simulate artificial time series for output, consumption and investment. These time series are decomposed in the frequency domain and Watson’s (1993) spectral measure of fit is applied to the business cycle frequencies.

The sequel of the paper is structured as follows: Section 2 describes the model, Section 3 briefly describes parameterization and solution techniques. Simulation results are presented and discussed in Section 4, while Section 5 is devoted to spectral analysis. Section 5 concludes.

2. The Model

I assume a growing small open economy where a deterministic exogenous growth trend $X_t = g^t,\ \ g > 1$, increases labor productivity:

$$Y_t = A_t \left(N_t X_t\right)^a \ K_{t-1}^{1-a}$$

Here Y_t is output, N_t is labor input and A_t is a stationary technology shock in period t, while K_{t-1} is physical capital at the end of period $t-1$ and used for production in period t. By assuming competitive markets, a is the share of labor income. Total time endowment is normalised to one, so that $0 \leq N_t \leq 1$. The unconditional expectation of A_t is denoted A.

It is convenient to analyse the model in trend adjusted (stationary) quantities, which are denoted by small letters. Dividing the above equation by X_t yields

$$y_t = A_t N_t^a \left(\frac{k_{t-1}}{g}\right)^{1-a}. \tag{1}$$

Aggregate demand can be decomposed into consumption c_t, gross investment i_t, government absorption g_t, and the trade balance tb_t:

$$y_t = c_t + i_t + g_t + tb_t \tag{2}$$

The capital accumulation equation (in growth adjusted quantities) is assumed to take the form

$$g k_t = f\left(\frac{g i_t}{k_{t-1}}\right) k_{t-1} + \left(1 - d\right) k_{t-1}, \tag{3}$$

where d denotes the constant linear depreciation rate and $f(\cdot)$ describes a concave adjustment cost technology in investment. Following Abel and Blanchard (1983) and Baxter and Crucini (1993), I will assume that there are no adjustment costs in the steady state by imposing the two conditions

$$f\left(\frac{g i}{k}\right) = \frac{g i}{k} \quad \text{and} \quad f'\left(\frac{g i}{k}\right) = 1$$

where, in general, variables without time index denote steady state quantities.

Under the assumption of capital mobility, agents in this economy can buy and sell foreign bonds on the world capital market. A bond is thought to be an asset which yields one unit of consumption in the next period. Clearly, the price of such a bond is $\left(1 + r_t\right)^{-1}$, where r_t is the world real interest rate. By letting b_t denote the (growth adjusted) net level of bonds that mature in period $t+1$, the value of net foreign bond holdings in period t is equal to the claims on foreign goods, i. e.

$$\frac{1}{1+r_t} b_t = \frac{b_{t-1}}{g} + tb_t + trf_t \tag{4}$$

where trf_t denotes the growth adjusted net foreign transfers received by the economy.

Let $s_t^g := g_t / y_t$ and $s_t^{trf} := trf_t / y_t$ be the share of government expenditures and the share of transfers in GDP, respectively, which are assumed to be exogenous processes. Using (1) and (4), equation (2) can be rewritten as

$$\left(1 - s_t^g + s_t^{trf}\right) A_t N_t^a \left(\frac{k_{t-1}}{g}\right)^{1-a} = c_t + i_t + \frac{b_t}{1+r_t} - \frac{b_{t-1}}{g} \tag{2‘}$$

With this setup, the representative individual solves

$$\max_{c_t, i_t, k_t, b_t, N_t} \quad U_0 = E_0\left[\sum_{t=0}^{\infty} \tilde{b}^t \frac{1}{1-s}\left(C_t - y X_t N_t^n\right)^{1-s}\right] \tag{5}$$

$$= E_0\left[\sum_{t=0}^{\infty} b^t \frac{1}{1-s}\left(c_t - y N_t^n\right)^{1-s}\right] \qquad y, s > 0, n > 1$$

subject to (2‘) and (3). Momentary utility here follows a specification introduced by Greenwood, Hercowitz, and Huffman (1988), henceforth GHH. The GHH specification has the feature that the disutility of labor increases with the growth trend, which can be interpreted as expressing technical progress also in household production activities. Household production, while not explicitly modeled here, may be quite important in the Jordanian economy, where many family members participate without formal pay in basic production activities. Moreover, Correia et al. (1995) have explored both GHH and standard preferences and found only GHH-preferences capable of replicating a rather high volatility of consumption in a small open economy. For Jordan, in fact, the volatility of consumption his fairly high, so GHH preferences are probably more adequate than standard preferences.

Note that $b := \tilde{b} g^{1-s}$, where b is assumed to be smaller than one to guarantee finite lifetime utility and $\tilde{b}$ is the preference parameter which discounts momentary utility in the growing economy.

Necessary conditions imply

$$y n N_t^{n-1} = a \frac{y_t\left(1 - s_t^g + s_t^{trf}\right)}{N_t} \tag{6}$$

$$\left(1+r_t\right)\frac{f'\left(\frac{\dot{g}_{t+1}}{k_t}\right)}{f'\left(\frac{\dot{g}_t}{k_{t-1}}\right)} - (1-a)\, g f'\left(\frac{\dot{g}_{t+1}}{k_t}\right)\frac{y_{t+1}}{k_t}\left(1 - s_{t+1}^g + s_{t+1}^{trf}\right) = f\left(\frac{\dot{g}_{t+1}}{k_t}\right) - f'\left(\frac{\dot{g}_{t+1}}{k_t}\right)\frac{\dot{g}_{t+1}}{k_t} + 1 - d \tag{7}$$

$$c_{t+1} - y\ N^{n}_{t+1} = \left(\frac{(1+r)\,b}{g} \right)^{\frac{1}{s}} \left(c_t - y\ N^{n}_t \right) \tag{8}$$

In the steady state we have

$$N^{n} = \frac{a}{y\,n}\, y\left(1 - s^{g} + s^{trf}\right) \tag{9}$$

from (6),

$$\frac{k}{y} = \frac{1-a}{r+d}\, g\left(1 - s^{g} + s^{trf}\right) \tag{10}$$

from (7)

$$\frac{i}{y} = \frac{g - 1 + d}{g} \frac{k}{y} \tag{11}$$

from (3),

$$\frac{b}{y} = \left[\left(1 - s^{g} + s^{trf}\right) - \frac{c}{y} - \frac{i}{y} \right] \frac{b}{b-1} \tag{12}$$

from (2‘), and

$$b = \frac{g}{(1+r)} \tag{13}$$

from (8). Note that the steady state determines *k*, *i*, and *b* only relative to *y*, which in turn depends on *N*. Hence steady state growth is compatible with any level of labor input. The level of *N* can be calibrated without further restrictions.

Equation (13) implies a restriction on the structural paprameter *b*, which will lateron be used to calibrate *b* from observed values of *r* and *g* Similarly, the model implies a restriction on *a*, since, by substituting (10) into (11) we can write

$$a = 1 - \frac{i}{y} \frac{r+d}{g-1+d} \frac{1}{1 - s^{g} + s^{trf}} \tag{11‘}$$

Therefore, *a* is determined by interest rate, depreciation rate and the shares of investment, government expenditure and transfers in GDP. This yields an alternative to calibrating *a* from the labor share which will be used lateron.

From (4), note that

$$tb + trf = \frac{b-1}{g} b$$

a positive steady state value of foreign assets *b* requires a negative sum of trade balance and net transfers *tb*+*trf*. This may seem counterintuitive at first sight. However, observe that the current account must be zero in the steady state, since otherwise *b* would either increase or decrease indefinitely. The current account is given by *tb*+*trf*+*rb*, hence for positive *b* the income balance is positive and this must be compensated by a negative sum of trade balance and net transfers.

Let us denote all variables (except *r*) as percentage deviations from the steady state (denoted by „hatted“ variables) and linearize equations (1), (2‘), (3), (6), (7), and (8) about the steady state. The log-linear analogues of these equations are given by

$$\hat{y}_t - \hat{A}_t - a\,\hat{N}_t - (1-a)\,\hat{k}_{t-1} = 0 \tag{1L}$$

$$\left(1-s^g+s^{trf}\right)y\hat{y}_t - ys^g\hat{s}_t^g + ys^{trf}\hat{s}_t^{trf} - c\hat{c}_t - i\hat{i}_t - \frac{b}{1+r}\hat{b}_t + \frac{b}{g}\hat{b}_{t-1} + b\frac{(r_t-r)}{(1+r)^2} = 0 \tag{2L}$$

$$g\hat{k}_t - (1-d)\hat{k}_{t-1} - (g-1+d)\hat{i}_t = 0 \tag{3L}$$

$$\hat{y}_t - \frac{s^g}{1-s^g+s^{trf}}\hat{s}_t^g + \frac{s^{trf}}{1-s^g+s^{trf}}\hat{s}_t^{trf} - n\hat{N}_t = 0 \tag{6L}$$

$$\begin{aligned} & r_t - r + (1+r)x\left(\hat{i}_{t+1}-\hat{k}_t-\hat{i}_t-\hat{k}_{t-1}\right) - (1-a)\frac{gy}{k}\left(1-s^g+s^{trf}\right)\left(x\left(\hat{i}_{t+1}-\hat{k}_t\right)-\hat{y}_{t+1}-\hat{k}_t\right) \\ & +(1-a)\frac{gy}{k}\left(s^g\hat{s}_{t+1}^g - s^{trf}\hat{s}_{t+1}^{trf}\right) + x\,\frac{gi}{k}\left(\hat{i}_{t+1}-\hat{k}_t\right) = 0 \end{aligned} \tag{7L}$$

$$\hat{c}_{t+1} - \hat{c}_t - \frac{y\,n\,N^n}{c}\left(\hat{N}_{t+1}-\hat{N}_t\right) - \frac{b}{cs\,g}(r_t - r) = 0 \tag{8L}$$

where *x* is the elasticity of the slope of the adjustment cost function evaluated at the steady state (recall $f'\left(\frac{gi}{k}\right)=1$):

$$x := f''\left(\frac{gi}{k}\right)\frac{gi}{k}$$

Equations (1L), (2L), (3L), (6L), (7L), and (8L) constitute a system of six linear difference equations for the two endogenous state variables b_t and k_t and the four control variables y_t, c_t, i_t, and N_t. Four exogenous processes, namely A_t, r_t, $\hat{s}_t^g, \hat{s}_t^{trf}$, drive the system. All exogenous processes except total factor productivity (TFP) are, in principle, observable such that we can estimate them as, say, first-order autoregressions. For factor productivity, I will assume that the innovation is observable: Let fdi_t denote foreign direct investment in Jordan in period *t* and suppose that FDI increases the level of TFP. Specifically, let $A(\cdot)$ be an arbitrary increasing function and suppose that TFP is given by

$$A_{t+1} = A_t^{r_A} A(fdi_t)^{1-r_A} \tag{14}$$

Clearly, in the steady state we have $A = A(fdi)$. Denote by k the elasticity of TFP with respect to FDI in the steady state. Linearizing (14) yields

$$\hat{A}_{t+1} = r_A \hat{A}_t + (1 - r_A)\, k\, f\hat{d}i_t \tag{14L}$$

The other exogenous processes follow simple first order regressions.

To solve the system, I use the method of undetermined coefficients as in Uhlig (1995). Denote endogenous state variables by *x*, controls by *y*,and exogenous shocks by *z*. All variables are indexed with the time period in which they are determined. Thus, by definition, in period *t* all equations that contain variables indexed *t+1* are expectational equations, while all (linear combinations of) endogenous variables indexed *t-1* are state variables. (The z_t-variables are, of course, also states). In matrix notation, the system of difference equations is then given by

$$Ax_t + Bx_{t-1} + Cy_t + Dz_t = 0, \tag{15}$$

$$Fx_{t+1} + Gx_t + Hx_{t-1} + Jy_{t+1} + Ky_t + Lz_{t+1} + Mz_t = 0, \tag{16}$$

$$z_{t+1} = Nz_t + e_{t+1}, \qquad E_t\left[e_{t+1}\right] = 0, \tag{17}$$

where *A,B,C,D,F,G,H,K,L,* and *M* are matrices collecting the coefficients of the linearized system. A solution can be found if

(i) matrix *C* has full column rank, and
(ii) matrix *N* has only stable eigenvalues.

These conditions are most easily checked after calibration.

We look for a non-explosive solution to this set of difference equations in state space form, i. e.

$$x_t = Px_{t-1} + Qz_t \tag{19}$$

$$y_t = Rx_{t-1} + Sz_t\,. \tag{20}$$

Such a solution is difficult to obtain in general, since it is probably impossible to give a closed form expression for *P*. Uhlig (1995) provides a theorem on how to construct *P* contingent on the solution of an eigenvalue problem. The solution will be non-explosive iff no eigenvalue of *P* is larger than one[3].

[3] The present model implies the well-known unit root property for consumption, cf. Hall (1978). Therefore, one of the eigenvalues of *P* is necessarily equal to one and hence the system is not stable. But it is non-explosive, and this is sufficient for the transversality condition to hold.

3. Parameterization

To proceed, we have to calibrate the model. The usual way to calibrate a would be to set a equal to the labor share, which averaged at 0.46 for Jordan over the last decade. This value is surprisingly low compared to industrialised countries. Moreover, with a=0.46 and standard values for other parameters equation (11‘) implies an investment share of 0.52, which is much higher than the observed value of 0.29. On the other hand, calibrating *i/y*=0.29 and using (11‘) to determine a yields a=0.70, which is perfectly in line with the labor share in advanced economies. My conjecture, therefore, is that the labor share taken from the national accounts is a biased estimate of the true labor share, since it does not account for labor input of family members in basic home and farm production activities. Hence, I prefer to fix *i/y*=0.29 and let a adjust endogenously.

Jordan experienced quite strong real growth over recent years; an estimate of the growth in real GDP yields g=1.05. An EU15 interest rate is not well defined prior to EMU. I approximate this rate conceptually by the long-run German interest rate due to the dominance of the Deutsche Mark in the European Monetary System. This gives an estimate of the steady state interest rate of 7.35% and by virtue of (13) implies b=0.976.

The utility discount factor of the growing economy, $\tilde{b}$, is related to b, by virtue of $b := \tilde{b} g^{1-s}$. Fixing $\tilde{b}$ at a conventional value of 0.98 thus implies $s = 1.09$. The other parameter of the utility function, n, is in principle, a free parameter; I just follow Greenwood et al (1988) and Correia et al. (1995) in setting n=1.7. For the depreciation rate I calibrate the standard value of ten percent per annum, which is widely used in the RBC literature. For y, the weight of labor in the utility function, and x, the elasticity of the slope of the adjustment cost function, I use reasonable benchmark values: y=1 and x=-0.01. Similarly, for k, the elasticity of TFP with respect to lagged FDI, I calibrate k=0.01. Note that in particular the adjustment costs of just one percent is a fairly small value, so that the adjustment cost technology by itself does not move the model far from a neoclassical benchmark model of an open economy with instantaneous adjustment of the capital stock.

The share of transfers in GDP (including workers remittances) is about 25% in recent years, while the government share is about 24%. I use these values as steady-state values. The activity rate of the labor force in Jordan is close to 0.67, such that I calibrate the steady-state value N=0.67. See Department of Statistics (2000) for the source of these values.

The exogenous processes are estimated as first-order autoregressions. The estimated coefficients are then used in the parameterization of matrix N in (17). Regression results are as follows:

Table 1

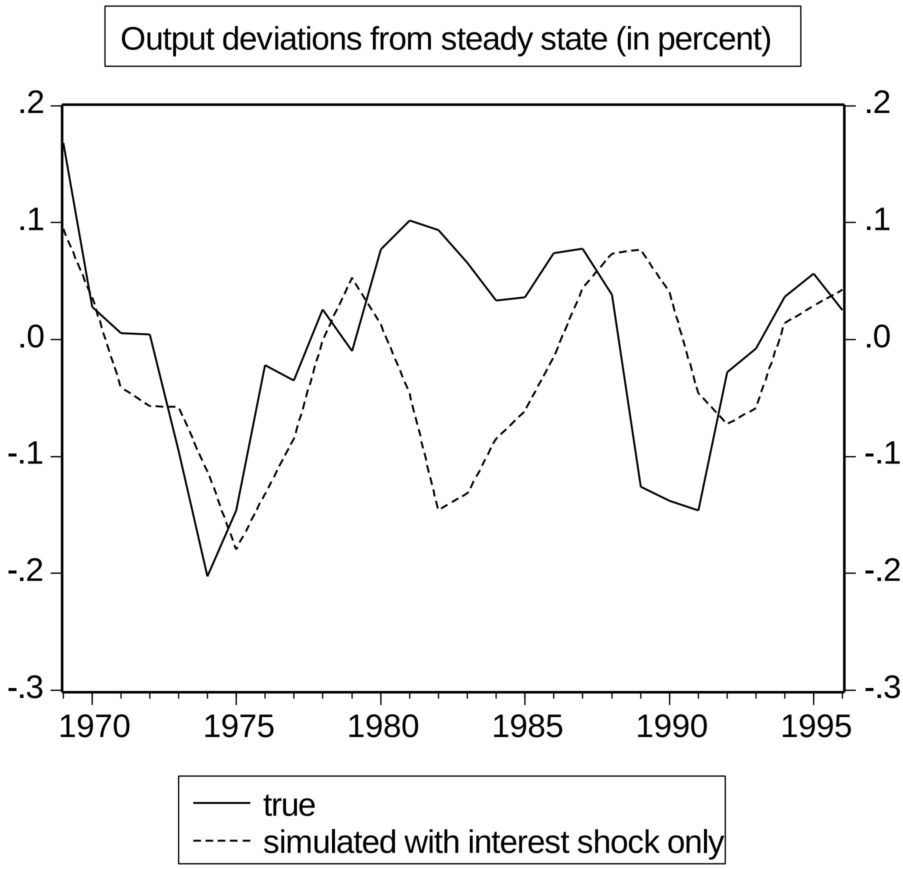
Variable	estimated coefficient of lagged variable	standard error	$\bar{R}^2$	P-value Q(4)
r_t	0.766**	0.121	0.513	0.063
$\hat{s}_t^g$	0.613**	0.132	0.356	0.848
$\hat{s}_t^{trf}$	0.798**	0.133	0.198	0.198
$\hat{fdi}_t$	0.221	0.206	0.245	0.245
**=significant at 1% level, *=significant at 5% level				

The significant estimates are used to parameterize the exogenous processes in the above model. For the FDI-process, the estimate is not significant and the Q-statistic suggests that this process is basically white noise. This justifies our modelling of FDI as an innovation to domestic TFP. For the TFP-process $\hat{A}_t$ I set the first order autocorrelation at 0.9 ($r^A = 0.9$) as in most of the RBC literature. The steady state value of A is derived from equation (1) evaluated at the steady state.

4. Simulation Results

I will now proceed to simulate the model and compare the simulated time series with their empirical analogues – HP-filtered logs of real GDP, private consumption and investment. To this end, let us first look at the effect of a interest shock on GDP, i. e. let us set all other shocks equal to zero over the whole sample period, while the observed EU interest rate is used as the exogenous impulse to the Jordanian model. This corresponds to the effects of a technology shock not directly transmitted to Jordan:

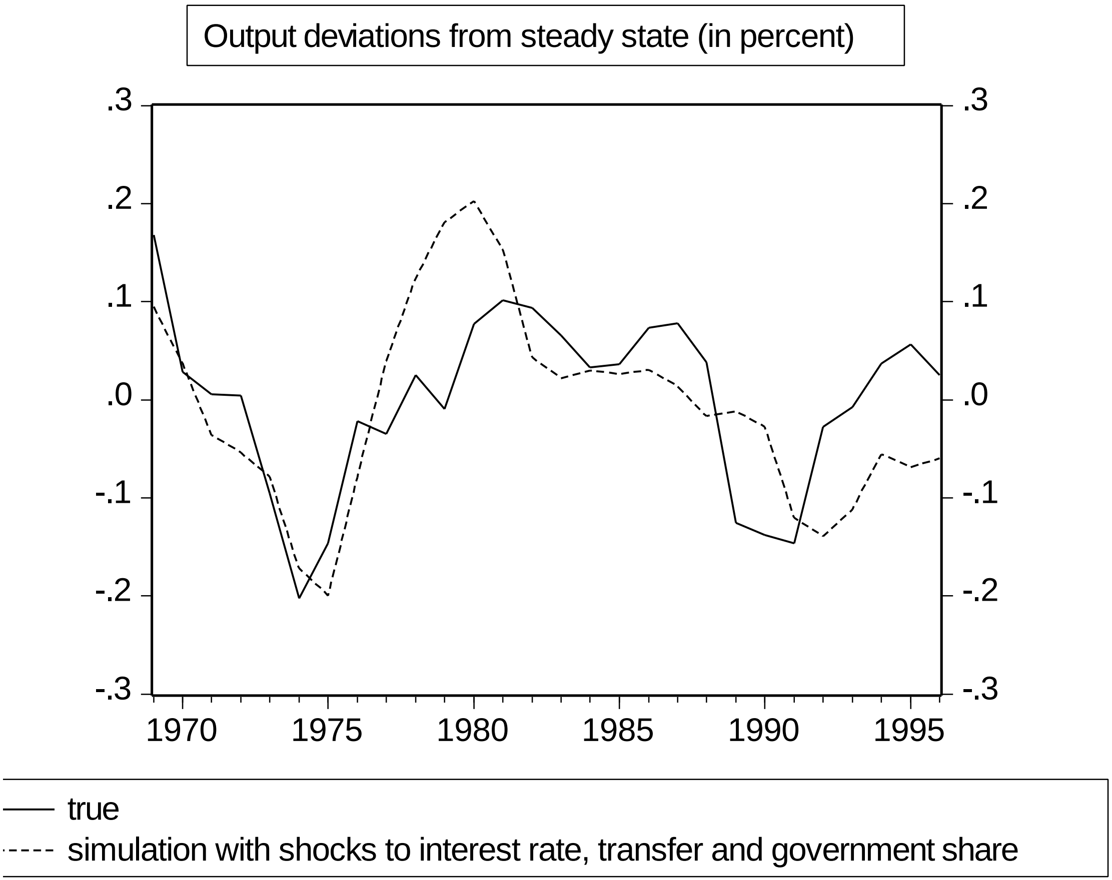
Figure 2



The correlation between true and simulated output series is fairly low, 0.27. However, the simulated series is actually quite close to the observed series for the first ten years or so. But with the outbreak of the second oil crisis the model being driven solely by EU interest rates predicts a severe recession in Jordan, which cannot be observed in the data. The reason for the continuing expansion in Jordan during the early eighties may be attributable to much higher transfers received in this and the following years – presumably from sympathetic oil exporting countries like Saudi Arabia. In fact, net transfers received by Jordan increased from $940 million in 1978 to $1767 million in 1979, $2302 million in 1980 and $2506 million in 1981. This enormous transfer of resources may be at the root of the expansionary fiscal policy which Jordan pursued in these years: Government consumption rose from JD 190 million in 1978 to JD 456 million in 1981 (and stayed high thereafter).

It is therefore interesting to see, how the model fares when shocks to transfers and the government share are added. The simulation results for output are given in Figure 3:

Figure 3



Again, the simulations are quite close to the observed values for most of the 1970s. During the second oil crisis, there is some overshooting of the simulated series, but otherwise the simulations are roughly in line with reality until 1988. The recession of 1989 and the following recovery are also reflected in the simulations, but with a lag of one to two years. The correlation of the two series 0.63 and hence much higher than in the former exercise.

Adding an additional FDI shock does not change this picture by much, cf. Figure 4. The effects are altered only marginally, it is in particular the fit in the mid-eighties which is somewhat improved. The correlation between true and simulated series increases to 0.65. In general, the present parameterisation does not allow for much explanatory power of FDI, since the effect of FDI on TFP is small (k=0.01), and TFP displays strong persistence with $r^A = 0.9$. Thus, TFP is rather smooth and cannot account for much of the observed fluctuations.

Let us briefly study the effects of the four shocks (interest rate, transfer and government share, FDI) on consumption and investment. Figure 5 shows the true (HP-filtered) consumption series along with the simulated series.

Figure 4

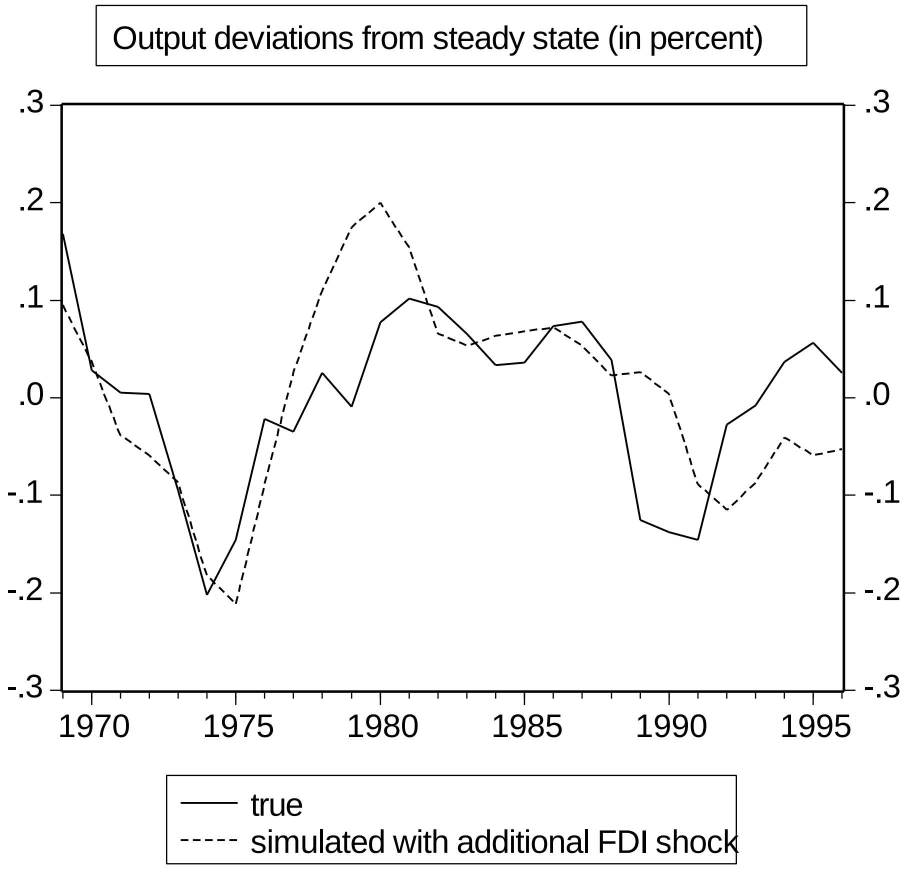
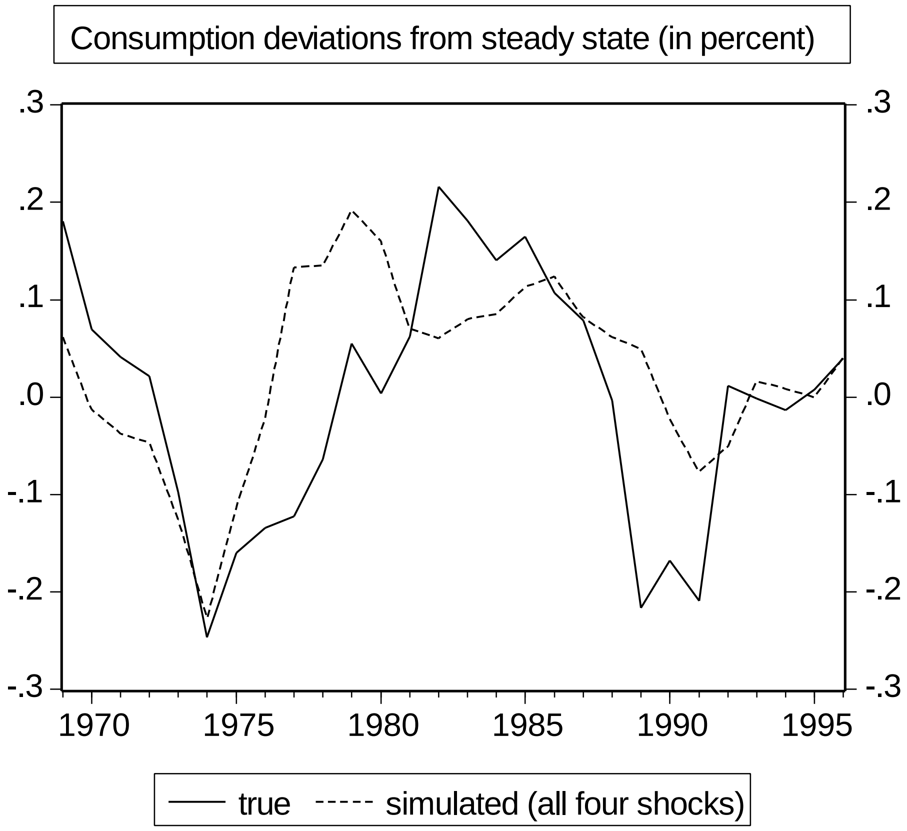


Figure 5



Qualitatively, the simulated series captures the main features of the observed consumption series, i. e. both recessions and the expansions of the 1980s and 1990s. Quantitatively, the simulated series is somewhat too high in the end of the 70s and somewhat too low in the beginning of the 80s. Also, the severe downturn of consumption around 1990 is not fully reflected in the simulations. The correlation between observed and simulated series is 0.54.

Nevertheless, on balance the simulations seem to be quite acceptable for consumption. This is remarkable, as RBC models incorporate optimal consumption smoothing and thus typically have difficulties matching the observed volatility of consumption, in particular in models of open economy with perfect capital mobility. Note that the volatility of consumption in the Jordanian data is extremely strong, with observed deviations from the HP-trend sometimes excceding 20 percent. In fact, it may be that this is a spurious feature of the Jordanian data, if (which I do not know) private consumption is calculated as residual in the national accounts statistics. The published series would then also include statistical errors and ommissions, and this could well lead to overstating the true volatility of consumption.

The picture is less satisfactory for investment, cf. Figure 6. The volatility of the simulated series is much too high andthe correlation between true and simulated series is a low 0.21. This cannot be cured by increasing adjustment costs, since in this case consumption volatitlity would increase. In fact, although the volatitlity of the simulated investment series is clearly unsatisfactory, it does indeed reflect some features of the observed series. This is most easily seen by computing a smoothed version of the simulated investment series, as in Figure 7.

Figure 6

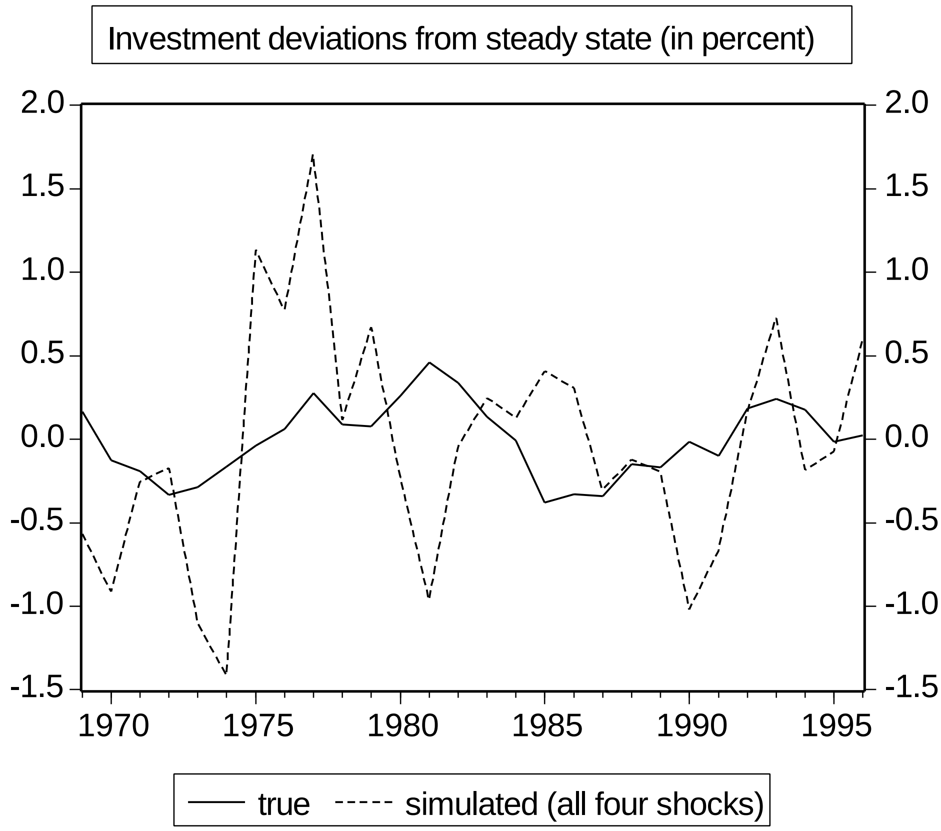
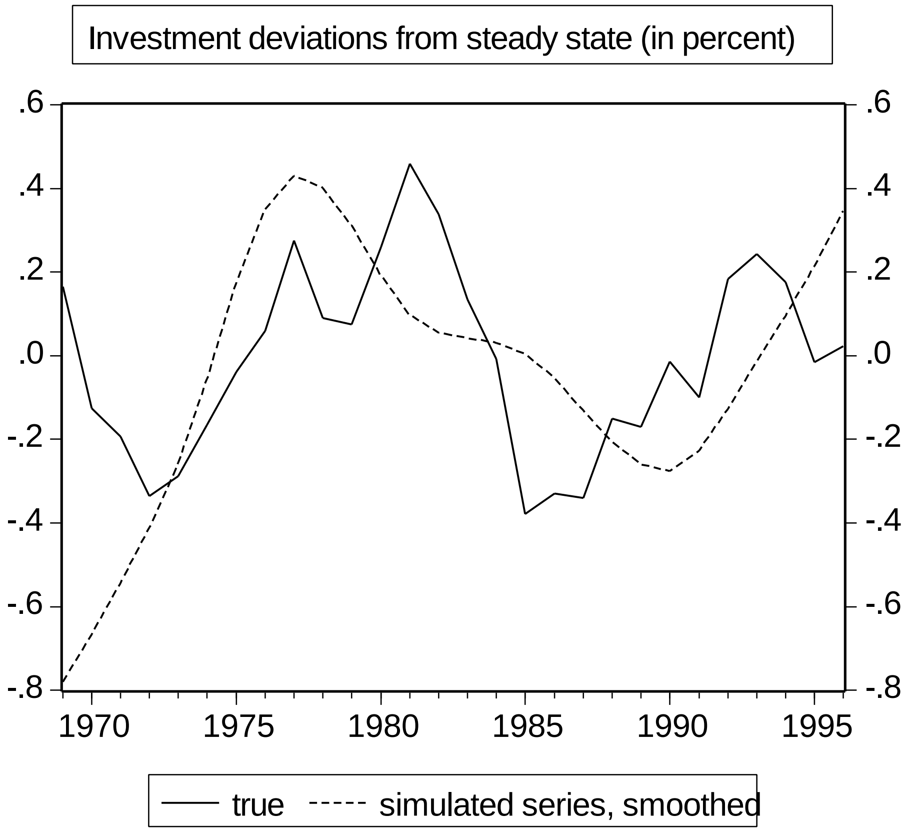
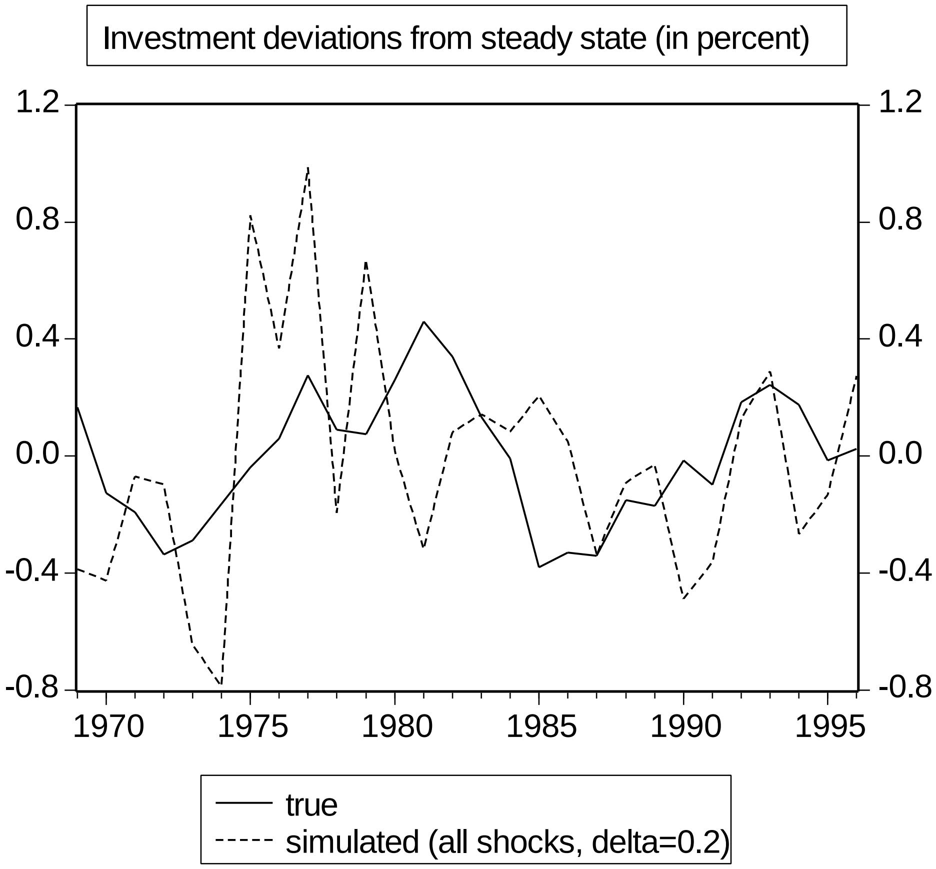


Figure 7



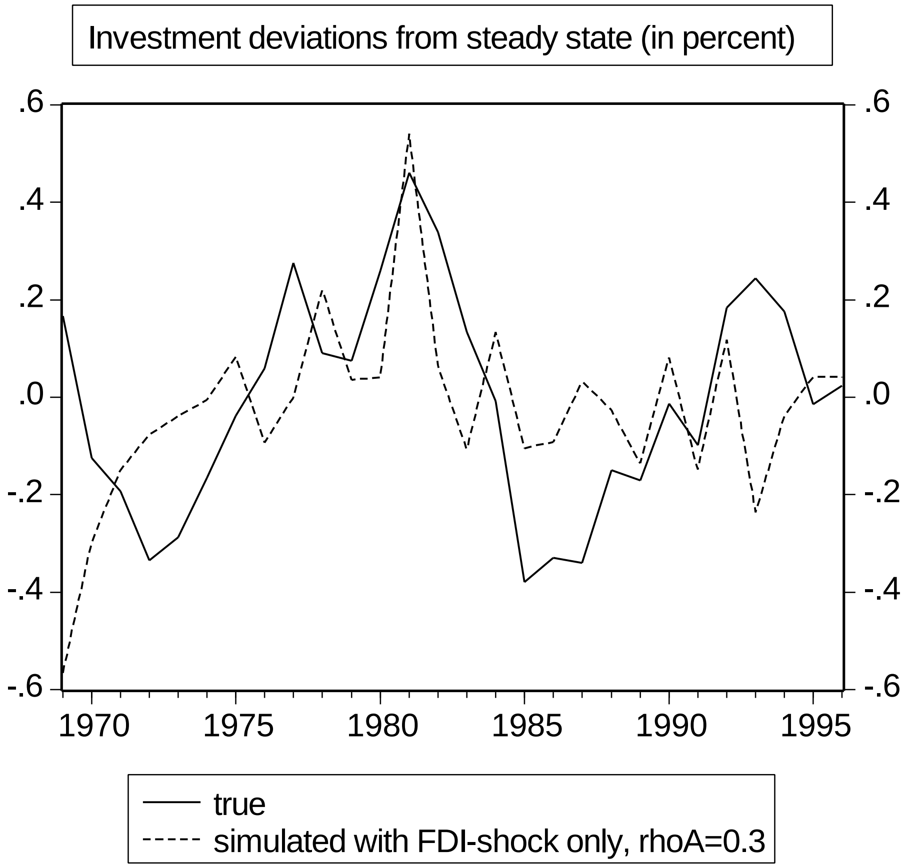
Is there a way to achieve better results for investment by changing the calibration? The variance of the investment series (which is much too high in the simulations) can be reduced by increasing the value of the depreciation rate, d For instance, with the non-standard value of d=0.2, the investment series would still be quite volatile, but the amplitude would be greatly reduced, cf. Figure 8. However, as we do not have evidence on physical debreciation of this magnitude, I will just note this fact and not explore this route any further.

Figure 8



It is probably difficult to successfully model investment without a more satisfactory treatment of FDI. There is some evidence, that FDI has considerable explanatory power for Jordanian investment, as the following exercise may demonstrate: Assume that TFP has only little persistence, e. g. $r^A = 0.3$. Simulating the model with an FDI shock only yields rather unsatisfactory results for output and consumption, but seems to indicate that the Jordanian investment boom of the early 1980s is mainly FDI-determined, cf. Figure 9. Apart from this period, however, ist is clear that other shocks are needed to obtain a reasonable fit to the observed data.

Figure 9



5. Analysis in Frequency Domain

While a comparison of observed and simulated time series may seem quite natural, this is actually not quite appropriate. The observed series have been HP-filtered, which in particular implies that the long-run component has been removed. The series derived from the model, on the other hand, are characterized by a unit root property stemming from the consumption Euler equation, hence these series do have a permanent component. A fair comparison between model and data thus requires, that the series be decomposed in the frequency domain and special attention should be given to the business cycle frequencies.

The appropriate methodology has been developped by Watson (1993). Watson does not assume that the model correctly reflects reality. Rather he interprets the model as an approximation to reality and tries to assess the magnitude of the error that has to be added to the model in order to make it compatible with the data. In frequency domain, this idea gives rise to a measure analogous to $1-R^2$ in ordinary regression, by comparing the spectral mass of the minimum required error relative to the spectral mass of the data.

I will briefly try to summarize the underlying ideas formally. Let $\mathbf{x}_t$ be a vector of variables generated by an economic model and let $\Gamma_{\mathbf{x}}(\cdot)$ be its autocovariance-matrix at lag t, i. e.

$\Gamma_{\mathbf{x}}(t) := \mathrm{E}[\mathbf{x}_t \mathbf{x}_{t-t}'] - \mathrm{E}[\mathbf{x}_t]\mathrm{E}[\mathbf{x}_{t-t}']$. The autocovariance generating function $A_{\mathbf{x}}(\zeta)$ is then defined on the unit circle as

$$A_{\mathbf{x}}(z) := \sum_{j=-\infty}^{\infty} \Gamma_{\mathbf{x}}(j) z^{j},$$

see Brockwell and Davis (1991). Since we focus on second moments, $A_{\mathbf{x}}(\zeta)$ is synonymous for the theoretical model.

Analogously, let $A_{\mathbf{y}}(\zeta)$ be the autocovariance generating function of the observed data vector $\mathbf{y}_t$. This function is unknown, but can be estimated. The crosscovariance generating function of $(\mathbf{x}_t', \mathbf{y}_t')'$ is $\left(A_{\mathbf{xy}}(z)\right)$ with typical element

$$A_{\mathbf{xy}}(z) = \sum_{j=-\infty}^{\infty} \Gamma_{\mathbf{xy}}(j) z^{j},$$

where $\Gamma_{\mathbf{xy}}(t) := \mathrm{E}[\mathbf{x}_t \mathbf{y}_{t-t}'] - \mathrm{E}[\mathbf{x}_t]\mathrm{E}[\mathbf{y}_{t-t}']$ is the crosscovariancematrix at lag t. Since $\Gamma_{\mathbf{xy}}(t) = \Gamma_{\mathbf{yx}}(-t)'$ we have

$$A_{\mathbf{yx}}(z) = \sum_{j=-\infty}^{\infty} \Gamma_{\mathbf{yx}}(j) z^{j} = \sum_{j=-\infty}^{\infty} \Gamma_{\mathbf{xy}}(-j)' z^{j} = \sum_{j=-\infty}^{\infty} \Gamma_{\mathbf{xy}}(j)' z^{-j} = A_{\mathbf{xy}}(z^{-1})'.$$

which in particular implies $A_{\mathbf{yx}}(e^{-iw}) = A_{\mathbf{xy}}(e^{iw})'$ für $0 \le w \le 2p$,.

For the approximation error $\mathbf{u}_t := \mathbf{y}_t - \mathbf{x}_t$ we thus find the autocovariance generating function as

$$A_{\mathbf{u}}(\zeta) = A_{\mathbf{y}}(\zeta) + A_{\mathbf{x}}(\zeta) - A_{\mathbf{xy}}(\zeta) - A_{\mathbf{yx}}(\zeta),$$

While $A_{\mathbf{x}}(\zeta)$ is known and $A_{\mathbf{y}}(\zeta)$ can consistently be estimated from the data, $A_{\mathbf{xy}}(\zeta)$ and $A_{\mathbf{yx}}(\zeta)$ are unknown and cannot be estimated, since we do not have a joint realization of the $(\mathbf{x}_t', \mathbf{y}_t')'$ process. Watson therefore determines a lower bound for $\mathbf{u}_t$ which is independent of possible assumptions on $A_{\mathbf{xy}}(\zeta)$. If this bound is low, then obviously it is possible to specify assumptions on $A_{\mathbf{xy}}(\zeta)$, which imply a good fit between model and data. Watson shows that the lower bound is unique and for each frequency w implies a linear transformation of the autocovariance generating function of $\mathbf{y}_t$ at $\zeta = e^{-iw}$, $0 \le w \le 2p$:

$$A_{\mathbf{xy}}(e^{-iw}) = G(w) A_{\mathbf{y}}(e^{-iw})$$

The precise definition of $G(w)$ can be found in Watson (1993).

Since an autocovariance generating function evaluated at $\zeta = e^{-iw}$ is proportional to its spectral density, we find the spectrum of $\mathbf{u}_t$ as

$$\frac{1}{2p} A_{\mathbf{u}}(e^{-iw}) = \frac{1}{2p}\left(A_{\mathbf{x}}(e^{-iw}) + (I - G(w)) A_{\mathbf{y}}(e^{-iw}) - A_{\mathbf{y}}(e^{iw})' G(w)' \right)$$

Defining

$$r_k(w) := \frac{\left[\mathrm{A}_{\mathbf{u}}\left(e^{-iw}\right)\right]_{kk}}{\left[\mathrm{A}_{\mathbf{y}}\left(e^{-iw}\right)\right]_{kk}},$$

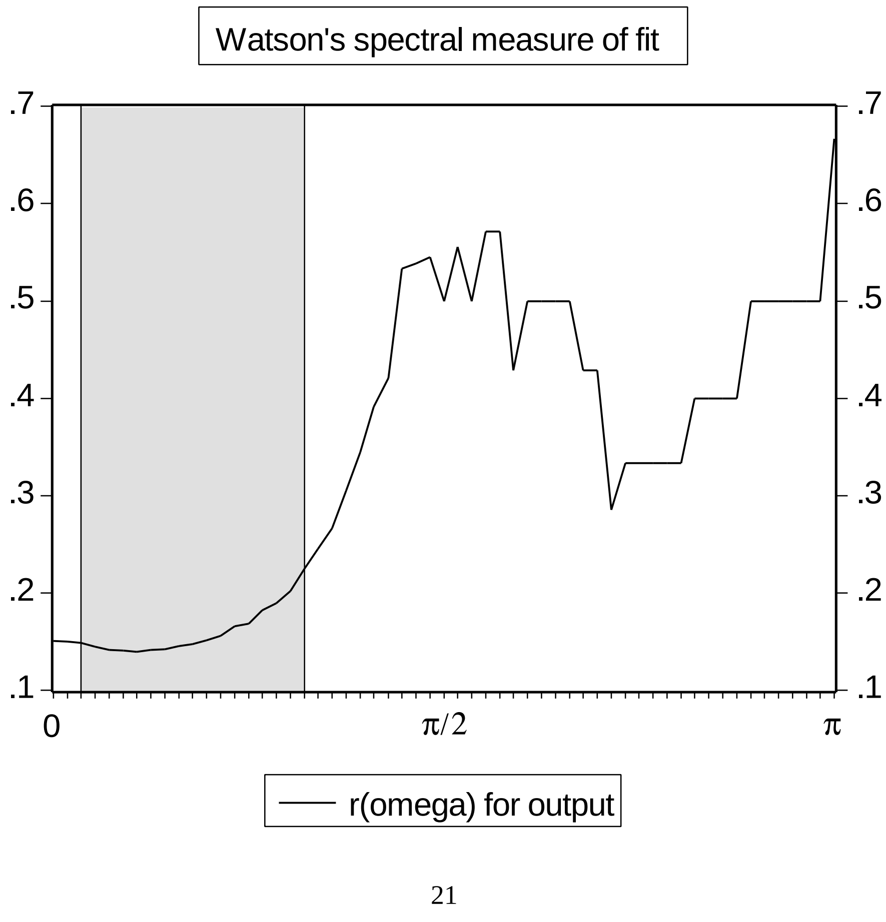
we have a spectral analogon to 1-R^2 in ordinary regression theory. Obviously, this measure can be integrated either over all frequencies

$$r_k := \frac{\int_0^{2p}\left[\mathrm{A}_{\mathbf{u}}\left(e^{-iw}\right)\right]_{kk} dw}{\int_0^{2p}\left[\mathrm{A}_{\mathbf{y}}\left(e^{-iw}\right)\right]_{kk} dw}$$

or just over a subset of frequencies, e. g. those considered business cycle frequencies. In this paper, I will consider as business cycle frequencies all frequencies associated with cycles of between 6 and 32 quarters length. In order to frame my discussion in terms of quarters, I interpolate the yearly time series linearly such as to obtain estimates for quarterly values.

Observe that $\mathbf{u}_t$ is generally not orthogonal to $\mathbf{x}_t$, hence $r_k(w)$ and r_k can be larger than one. This is analogous to R^2 in a linear regression without constant term. Since the definition of the spectral measure is inverse (similar to 1-R^2), small values of the measure indicate a possibly good fit. Observe further that $r_k(w)$ is invariant to linear filtering. Since the HP filter can be well approximated by a linear filter (and is actually computed as a linear filter), HP filtering is not a concern in this analysis. See e. g. King und Rebelo (1993). However, the integrated measure r_k.is not invariant under linear filtering, since the gain is affected.

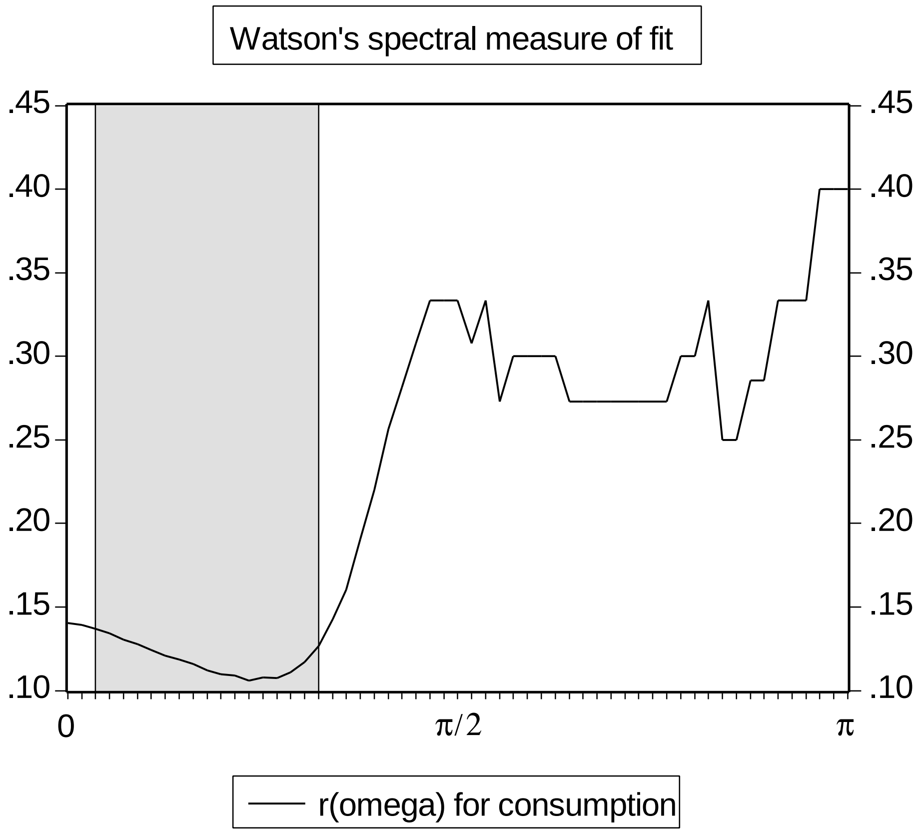
Figure 10



In applying Watson's measure of fit, I depart slightly from his suggested approach, since I do not *compute* the true model spectrum but rather *estimate* this spectrum from the simulated time series above, i. e. from the time series obtained from the model under the standard calibration and subject to the four observed shocks. Doing so is necessary, since the unit root property in the model implies that the model spectrum is actually infinity at frequency zero. Estimates for the spectrum at frequency zero, however, always result in finite values, regardless if simulated or observed time series are considered. This is due to the well-known finite-sample bias of spectral estimators. Estimating both the model and the data spectrum thus implies that the model spectrum also involves a bias and thus guarantees that model and data are treated symmetrically.

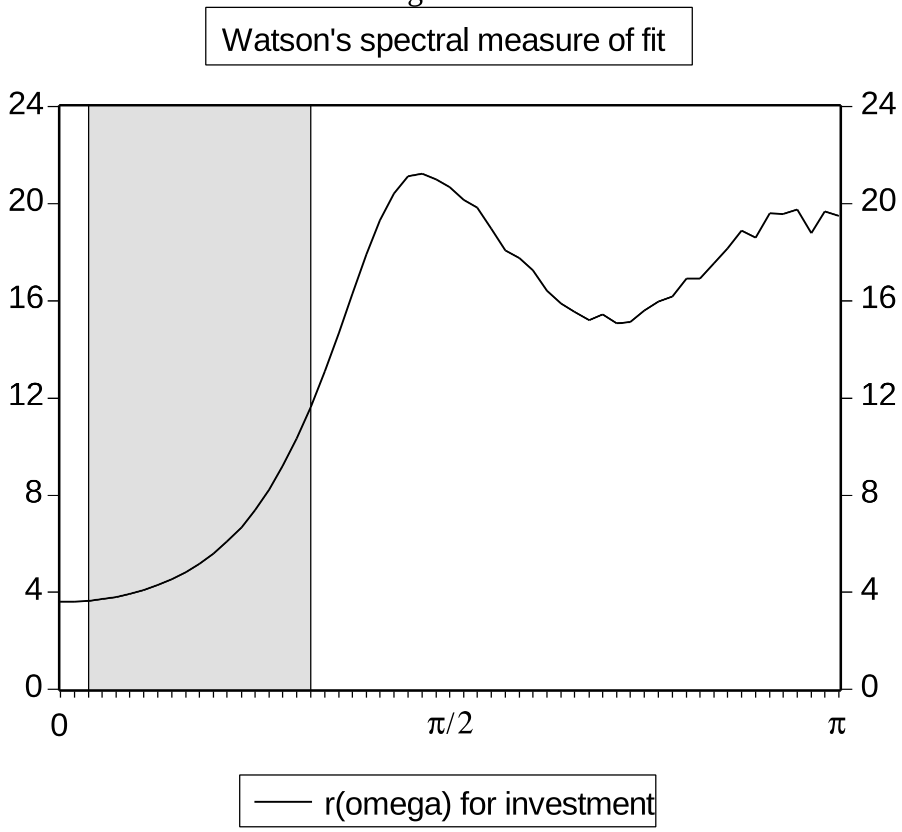
Figure 10 gives Watson's measure of fit for output. The shaded area denotes business cycle frequencies. It is easily discernible that the fit over these frequencies is quite satisfactory, the integrated measure over this range is 0.15. The fit is much worse for short run frequencies, which, however, are not central to the analysis in this paper.

Figure 11



A very similar result obtains for consumption. Here the value of the integrated measure over business cycle frequencies is 0.13, cf. Figure 11. Not surprisingly, for investment the fit is much worse, with a value of the integrated measure of 4.79 over business cycle frequencies.

Figure 12



Finally, coherences can be studied. For consumption and output, we again find that the model is very close to the data over business cycle frequencies, cf. Figure 13, while there are considerable discrepancies between model and data for the coherence between investment and output, cf. Figure 14.

Figure 13

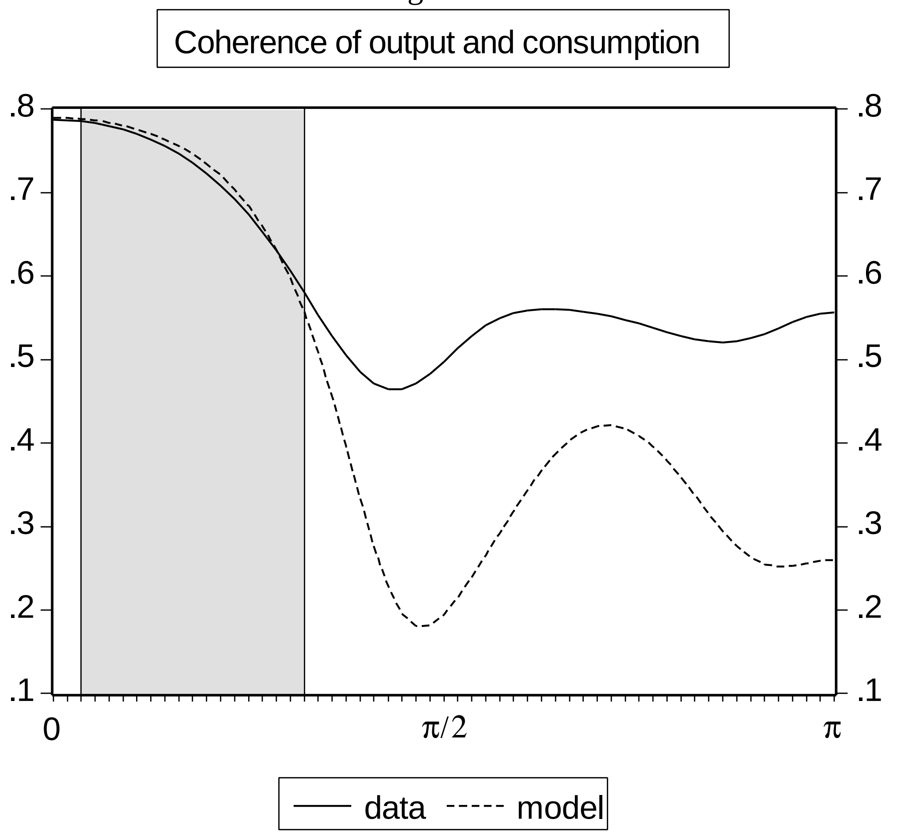
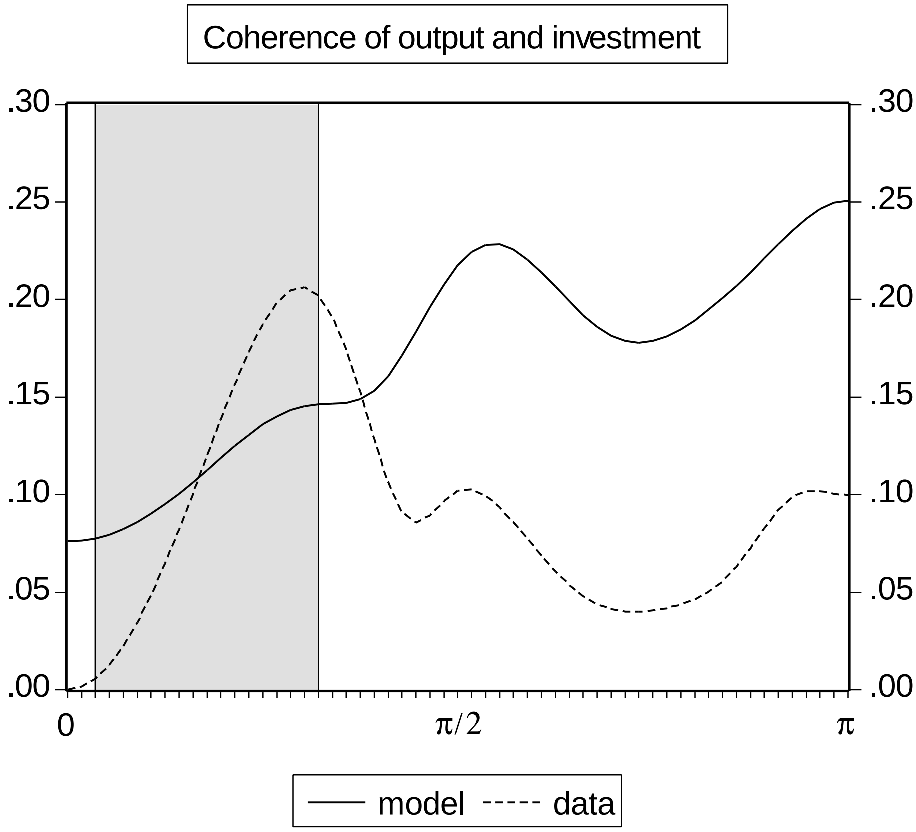


Figure 14



Coherence of output and investment
.30
.25
.20
.15
.10
.05
.00
0
π/2
π
model
data

6. Conclusions

This paper explored the negative correlation between business cycles in Jordan and the EU15. Since Jordan's economic performance has certainly only a negligible influence on the European GDP, this seems to be the typical case of a small and a large economy. However, Jordan's economic performance is unlikely to be severely affected by direct (trade related) impulses from Europe, since its trade share with Europe is traditionally small. Moreover, such a linkage would typically induce a positive correlation of business cycles.

The transmission channel explored in this paper is of a more indirect nature. Total factor productivity is assumed to increase in Europe due to technological innovations. These advances in TFP spill over to Jordan only in the form of FDI – if there are no increases in FDI, then Jordan does not take advantage from European innovations beyond trend developments. However, positive European TFP shocks spill over to Jordan in their effect on world real interest rates, which increase with the marginal productivity of capital. With free capital mobility, Jordan is thus exposed to negative shocks to Tobin's *q* in the case of European advances in TFP which do not disseminate to Jordan.

A dynamic stochastic equilibrium business cycle model specified along these lines is used to study the quantitative importance of this transmission channel. While a long-run interest rate shock alone is not capable to produce more than a rough approximation to the observed output fluctuations in Jordan, a refined model version which also accounts for shocks to net foreign transfers, government share and FDI, is much more successful. Using a standard calibration, both output and consumption are reproduced reasonably well in simulation exercises which use merely observed time series for the exogenous impulses.

The fit is less satisfactory for investment, which is too volatile in the simulations. However, the model may still capture some essential features of actual investment, since smoothing the simulated investment series results in a series much closer to reality. Thus, with rather small adjustment costs in investment activity, it seems that the model overstates the true flexibility of investment behavior. A higher than standard depreciation rate also brings investment closer in line with observed data. However, it is not easy to find a parameterization which is equally satisfactory for output, consumption and investment.

In order to improve the fit of invesment, further reasearch might be well advised to improve on the modelling of FDI (and technology transfer). This aspect has been kept very basic in the present analysis, in order to specify the transmission channels as simple as possible. Perhaps this is one reason, why a spectral decomposition shows that the fit of simulated series is generally not satisfactory in the range of short-run fluctutations. Conversely, however, Watson's measures of fit show that the model is particularly successful in the range of business cycle frequencies, which are, of course, at the heart of this paper's analysis. Again, we find that the model replicates output and consumption (and their coherence) very well, while investment (and its coherence with output) is less successfully replicated.

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