Growth trends and business cycles in the Finnish forest sector 1900-2000

Linden, Mikael

ISBN 952-458-411-5
ISSN 1458-686X
no 9

Growth trends and business cycles in the Finnish forest sector, 1900-2000

*Mikael Linden *)*
Department. of Business and Economics, Yliopistokatu 7,
P.O. Box 111, University of Joensuu, FIN-80101
E-mail: mika.linden@joensuu.fi

ABSTRACT. A short survey of business cycle models is given as an introduction to analysis of the evolution of Finnish GDP and forest sector output in the 20th century. The trend and cyclical features of yearly observations of GDP and forest-sector outputs from 1900 until 1999 are detected with different methods. The trend slopes in all four series contain large swings in the pre-1950 period. There is a declining growth trend up to the early 1990's, and the business cycles are also longer in the first half of the century than in the second half. Forest-sector cycles are shorter than GDP cycles, although the cycle coherence is high between all the series. The GDP series have predictive power over all the other series. The output value of forestry is determined by the other sectors. One co-integration vector exists between the four series. The output of the wood-products industry is weakly exogenously determined by GDP and by the outputs of the other forest sectors. An impulse-response analysis reveals that the GDP-cycle-shock effects are well detected in all forest series, although their duration is short. The wood-industry effects are most permanent among the weak forest-sector shocks. The results obtained in this study is most easily understood with the Keynesian type two sector model of business cycles.

---

*) Special thanks to Jussi Uusivuori, Ph.D , and anonymous referees for their helpful comments. This research note is part of the project, *"Business Cycles, Information Technology and Globalisation in the Finnish Forest Sector"*, funded by TEKES/2001 .

1. Introduction

The 20th century constitutes an important era for the Finnish economy and society. A small and remote nation gained its independence, and an economy based on the primary sector changed to a post-industrial society in which high technology with its global impact is predominant. The Finnish forest sector, consisting of the wood producers and the forest industries, has played a major role in the evolution of Finnish society and economy in the last century. During the first part it, the importance of the primary sector was also emphasised by the fact that domestic fuel wood was the nation's primal energy source. This importance declined rapidly in the second part of the century and the forest industries became one of the main sources of economic growth in the Finnish economy. Figure 1 shows these interesting long-run patterns. In the early part of the century, the GDP share of forestry output was close to 18%, but the forest-industry share was only 4%. By the end of the century these figures were totally inter-changed, showing the importance of the forest industry.

If the percentage shares are changed to actual output values at 1990 GDP prices (Figure 2), it is clear that the value of the output of the pulp and paper industries increased remarkably during the 20th century. The growth of the wood-product industries was rapid, but forestry output increased at a slower pace than GDP, and started to decline in the early 1980's. Figure 2 also reveals the main focus of this paper. All the series show clear trends and clearly-detected cyclical patterns. Accordingly, the aim here is to analyse these trends and cyclical patterns in detail. A short survey of different business cycle models are given in Section 2. This enables us to cast the empirical findings in coherent theoretical framework. Dynamic time series methods are used to determine how forest-sector series are related to each other, and to the GDP-series. The different

Figure 1. GDP-shares of forests-sector outputs, 1900-1999

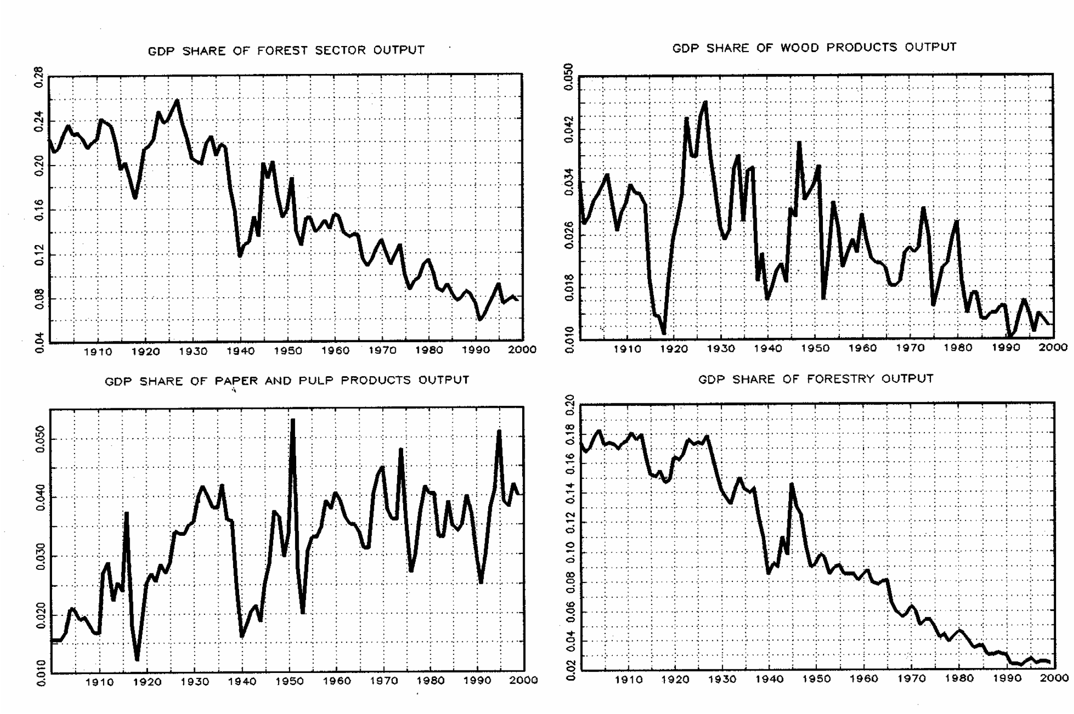
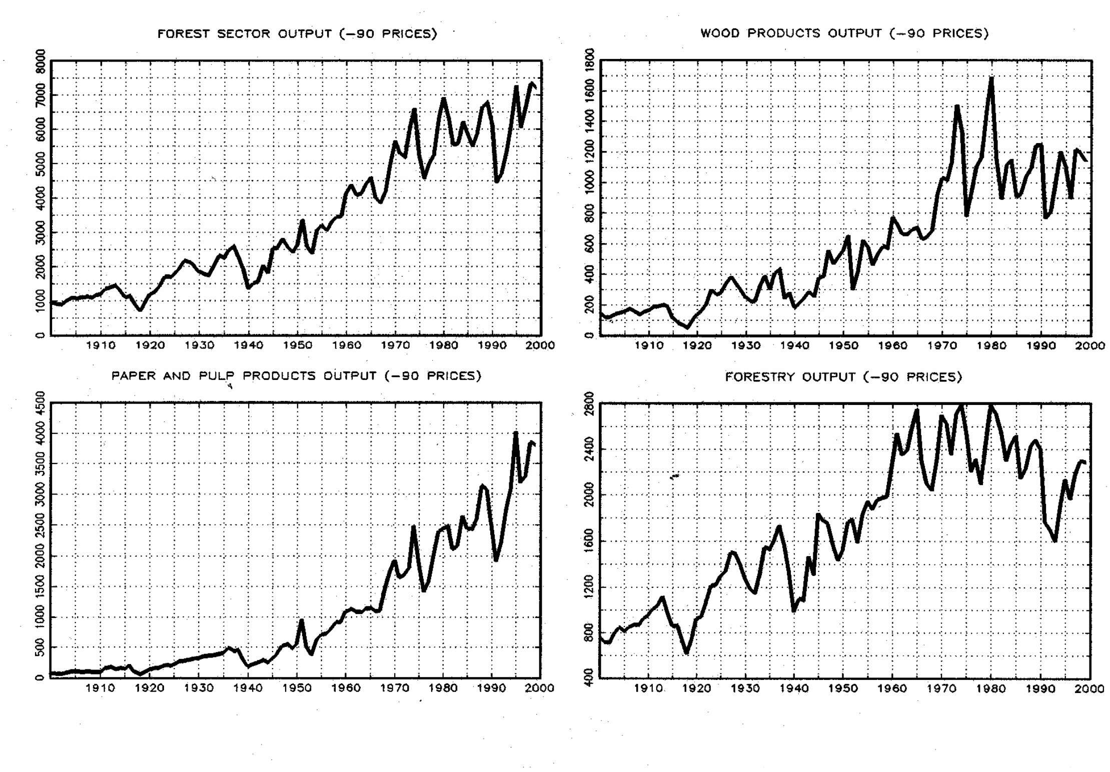


Figure 2. Forest-sectors outputs at 1990 prices, 1900-1999



empirical methods, both parametric and non-parametric, described in Sections 3 and 4 give a detailed picture of the dynamic growth and cycle effects between GDP and the forest sector in Finland during last century. More precisely, the aim is to establish the shock propagation mechanism in the forest sector and its relation to GDP. By shock propagation we mean how unanticipated large changes in one part of the economy affects other sectors of the economy. Section 5 gives a summary of empirical findings of paper and a discussion related to different theoretical business cycle models.

2. Models of business cycles

The business cycles have always been one of the most important research agendas in the economics. Since days of classical economics (e.g. Marx and Malthus, see Eltis 1984) the problem of uneven growth of capitalist economy has been addressed both in theoretical and empirical economic analysis. The empirical fact that upswings and downswings in relation to trend growth occur in irregular magnitude and time periods have been the forefront theoretical macroeconomic issue since the days of Keynes in 1930's. Keynes did not provide any coherent model of business cycles and the Keynesian macroeconomics developed since then was targeted to control the business cycles with different demand policy measures. The cause of business cycles were found in "animal spirits" of investors and changes in consumption patterns influencing aggregate demand. The first formal models of business cycles with Keynesian blend was provided by Hicks (1950) and Samuelson (1939). The cyclical results of both models were based on the properties of second order difference equations. Casting the idea of these models in two sector economy model we obtain

$$\begin{aligned} Y_{1,t} &= a_0 + a_1 Y_{t-1} \\ Y_{2,t} &= b_0 (Y_{1,t} - Y_{1,t-1}) \\ Y_t &= Y_{1,t} + Y_{2,t} \end{aligned}$$

After inserting the first equation in the second equation in current and in lagged form, and then in the third equation, we obtain

$$Y_{2,t} = b_0(a_1 Y_{t-1} - a_1 Y_{t-2})$$
$$Y_t = a_0 + a_1 Y_{t-1} + Y_{2,t}$$

$\Rightarrow$

$$Y_t = a_0 + a_1(1 + b_0)Y_{t-1} - b_0 a_1 Y_{t-2} \,.$$

This is a linear second order difference equation for the whole economy. The cyclical solution depends on the specific parameter values. If $1/a_1 = b_0$ a regular cyclical solution is obtained. Damped oscillation is found when $1/a_1 > b_0$. Note that second order difference equation with similar properties can be also solved for sub-sectors $Y_{1,t}$ and $Y_{2,t}$. Thus the model above is interesting in this context. It says that output of sector 1 is driven by lagged output (demand) from the whole economy but sector 2 is driven by difference of output of sector 1. If we assume that sector 1 corresponds to the part of economy (including all exports) without the forest sector and sector 2 is the forest sector we see that the model structure assumes that forest sector is determined by rest of economy.

It is know for a long time that non-linearity can create cyclical solution in dynamic modelling. Goodwin (1951) was on the first to develop models of business cycles along these lines. Assume that the economy has two sectors: a consumption sector and capital sector. In the closed economy, real consumption is determined by

$$C = \alpha + \beta Y$$

and real income by

$$Y = C + \dot{K} \,.$$

Here C is real consumption, Y is real net national product (*NNP*), and K is the real capital stock, $\dot{K} = dK/dt$ is the rate of investment, and $\alpha > 0, 1 > \beta > 0$. Dynamics is introduced by a non-linear investment function of form

$$\dot{K} = \begin{cases} k_1 > 0, & K < K* \\ 0, & K = K^* \\ k_2 < 0, & K > K* \end{cases}$$

where $K^* = \lambda Y$ is the desired capital stock in the capital sector and $\lambda > 0$. The NNP moves according to

$$Y = (\alpha + \dot{K})/(1 - \beta)$$

which produces a crude cycle. The economy is unstable because investment shifts radically from k_1 to k_2. This simple model has one important implication. The capital intensive or the investment sector of economy causes fluctuations to whole economy and to the consumption sector. The forest industry has been the major capital sector in the Finnish economy and its investment decisions had effects on the whole economy up till 1980's.

Although these type of models are intuitive and illuminating they contain many problems. First, the models are highly reduced and ad hoc in nature. Any deeper theoretical justification for them is missing. Second, the interesting results depend on some specific parameter values. Lastly, obtained cyclical results show regular periodic motion. The observed economic series show trend growth added with irregular persistent oscillations. The trend mean reversions can last almost decades. Some irregularity can be added to above models with stochastic disturbances (i.e. ARMA, ARIMA and TAR type models) but their inclusion does not increase the predictive power of models.

Two sector neo-classical growth models can be seen as response to the first problem. In these models there are two kinds of goods, i.e. capital and consumption goods, each produced by sector specific capital and labour as inputs in sectoral production functions. Perfect competition and profit maximization conditions are derived with exogenously given wage, interest rate and sectoral prices. The conditions for a unique solution in the static models are demanding (see Uzawa 1963, Inada 1964, Ramanathan 1982, Ch. 11). The conditions that give a cyclical result depend on the wage and capital income saving rates and on the initial levels wage rate and factor intensities $k_i = K_i / L_i \;\; i = 1, 2$. However, the stable unique solution needs that $k_2 > k_1$, i.e. that consumption sector is more capital intensive than the investment sector. Since we know that forest sector, especially forest industry, is more capital intensive than the rest of economy multiple or cyclical solutions are expected.

Since 1970's the theoretical business cycle research has evolved along two quite separate lines although both approaches stress the non-linearity and endogeneity of business cycles. The literature before 1970's was largely based on the linear-stochastic difference equations and awkward threshold models. Nowadays, both the Goodwin-Marx tradition and so-called endogenous cycles school use the theory of non-linear differential systems extensively. The main difference between the schools is their different respect to optimizing economic agent paradigm. The Marx-Goodwin approach models the economy with aggregate entities without the micro foundation that are highly stressed by endogenous cycle schools. Both schools uses high powered mathematics and almost any kind of periodic solutions (e.g. limit cycles, bifurcations, hysteresis and chaotic solutions) are obtained (see Gabisch & Lorenz 1987, Jarsulic 1993, Mullineux & Peng 1993). Note that models in real business cycle (RBC) school, popular in macroeconomic research since the 1980's, are build on the optimization framework with linear-stochastic difference equations. The aggregate fluctuations are generated with exogenous shock propagation mechanisms. The impact of RBC school on the theory of endogenous business cycles has been limited (Dore 1993). However the Keynesian type endogenous cycle models stemming from the work of Kaldor and

Kalecki were first important papers on the complex dynamic analysis (Gabisch & Lorenz 1987).

Although the two- or multisectoral models have been quite few in both schools, the non-linear approach entails that periodic solutions are often obtained. In the Marx-Goodwin tradition e.g. Sato (1985) provides an interesting model. The capital and consumption goods are produced with labour and capital with fixed proportions. Both inputs are perfectly mobile across the sectors. The important assumption in the Marx-Goodwin tradition concern the investment and income distribution. All wages are assumed to be consumed but all profits are saved and invested. The growth in the real wage depends on the level of excess labour and on the Phillips curve. The total capital stock equals with the output of capital sector. Sato derives a system of differential equations for growth of real wage rate and capital stock of consumption sector. Cyclical movements do not occur if labour force growth is zero or capital/labour ratio in the consumption sector is sufficiently higher than that of the capital goods sector. If our economy consist of capital intensive forest sector and non-forest sector the above conditions for non-cyclical solution are hardly met.

The paper by Boldrin and Deneckere (1990, see also Boldrin 1985, Benhabib and Nishimura 1979, 1985) is an good example of modelling strategy in endogenous cycle school. The set up is similar to the neoclassical two sector model but now the economy is in the competitive equilibrium and the target is the derive the sequence of optimal aggregate capital stock with dynamic programming methods. The basic parameters of the model are: the share of income in the consumption sector, the capital/labour ratio in the investment sector, and the discount factor. These determines stability conditions of the model. Cyclical and chaotic paths are most often found because of factor intensity reversals. Benhabib and Nishimura (1979) shows that the Hopf bifurcation and stability of closed orbits are expected in the optimal control model of typical neoclassical multisectoral optimal growth model. The general stationary result (the turnpike theorem) in the optimal multisector growth models is valid if the discount rate is enough low. However, if the agents are too impatient just anything can happen in concave dynamic programming models with infinite horizon (Montrucchio 1992). However high discount rate is not necessary condition for periodic and chaotic solutions in optimizing models (see Boldrin & Woodford 1992).

Much of current research is focused on the chaotic solution of models. Chaotic solution has some advantages over other cyclical solution since the solution is aperiodic or irregular. This corresponds closely the empirical fact the business cycles are asymmetric, recurrent but not fully periodic. Models that are rich in dynamics are actually rather easy to build. In the following propose a simple alternative that contains some aspect of preceding alternatives. Assume that the operational real surplus or profits of the firm is given by

$$V_{t+1} = q_t - (1+\delta)(w_t L_t - V_t)$$

where q_t is the firm's output, δ is the discount rate, w_t is the given real wage level, and L_t is the labour input. Output is a linear function of labour input $q_t = hL_t$. The competitive real wage level $h = w_t$ is assumed. Inserting these in the above equation and noting that the short run labour demand is determined by the profit level $L_t = G(V_t) \approx aV_t^2$ we have

$$\begin{aligned} V_{t+1} &= hL_t - (1+\delta)[hL_t - V_t] \\ &= -\delta hL_t + (1+\delta)V_t \\ &= (1+\delta)V_t - \delta haV_t^2 \\ &= A_1V_t - A_2V_t^2. \end{aligned}$$

Using scaling $x_t = A_2V_t$ gives

$$A_2V_{t+1} = A_1A_2V_t - A_2{}^2V_t^2$$

.

$$\Leftrightarrow \qquad x_{t+1} = A_1x_t - x_t{}^2 = A_1x_t(1-x_t)$$

This is a logistic map equation that is standard tool in the chaos analysis. A solution exists when $0 < A_1 \leq 4$. An uniform converge to steady state is provided when $A_1 < 3$, but values $3 < A_1 < 3.57$ give limit cycles and with $A_1 > 3.57..$ chaotic dynamics is obtained. Note that A_1 depends only on parameter δ. Thus if the discount rate is high, the time motion of surplus is cyclical. Some more interesting dynamics is obtained if we assume that A_1 is not a constant but a random variable in time

$$A_t = A_1 + \varepsilon_t$$

where $\varepsilon_t \sim dist(0,\sigma^2)$ with narrow range of random values. This alternative results in dynamics where different solution alternatives may succeed one other.

The empirical testing of implications of different cyclical models described above are still infant. Many models are at too high level of abstraction without practical and testable restrictions. Economic time series are too short to give definite conclusion concerning the postuled chaotic features in economic systems. Most aggregate economic time series are trending both in deterministic and stochastic sense. This is clear mark of non-convergent behaviour. The detreding leads us to oscillating series but most of theory models are silent about trend and cycle decomposition. The theoretical and empirical business cycle research has progressed so far quite independently from each other. Empirical regularities concerning the business cycle asymmetries, durations and co-incidences in different countries are well-documented (see e.g. Diebold & Rudebush 1999, Woitek 1996, Razzak 2001, Gregory et al. 1997, Kontolemis 1997) but these results are still only indirectly theory decisive. This partly explains that linear-stochastic difference equations with or with out exogenous shock propagation mechanisms are still very active research agenda (Horvath 2000). However some new endogenous cycle model alternatives are developed that may give some promising testable impactions (Matsuyama 1999, Nishimura & Yano 1995, Fatas 2000).

3. Measuring trends and cycles

Long economic time series contain typically both long run and short run components that reveal the different aspects of economic growth. Trends depict the long run growth while the cycles correspond to the short term regular variation around the trends. Thus it is important to have in the growth analysis well –founded trend and cycle estimates.

The problem of optimal trend- and cycle-component extraction is well known (e.g. Gomez 1999, Harvey & Jaeger 1993), and many different solutions have been suggested. The smoothing spline-approach is used in this context because it is flexible enough to handle slowly evolving economic series. Basically, all economic time series consist of the following components:

$$X(t) = F[trend(t), cycle(t), noise(t)].$$

Under the additive assumption, the function F( ) has the following form:

$$\begin{aligned} X(t) &= trend(t) + cycle(t) + noise(t) \\ &= T(t) + C(t) + \varepsilon(t). \end{aligned}$$

The estimates for the trend $T(t)$ and the cycle component $C(t)$ can be obtained in sequence using smoothing splines on the original series $X(t)$, and on the de-trended series $X(t) - \hat{T}(t)$. The smoothing-spline approach is the solution to the following programming problem (Green & Silverman 1994). Choose λ in such a way that a smooth trend estimate $\widehat{T}(t)$ for $X(t)$ is obtained. In other words

$$\underset{\lambda}{\boldsymbol{MIN}}\{\sum_{t=1}^{T}\{X(t)-T(t)\}^2+\lambda\int_a^b\{d^2T/dt^2\}^2\,dt\}$$

$$(a \le t_1 \le .... \le t_T \le b),$$

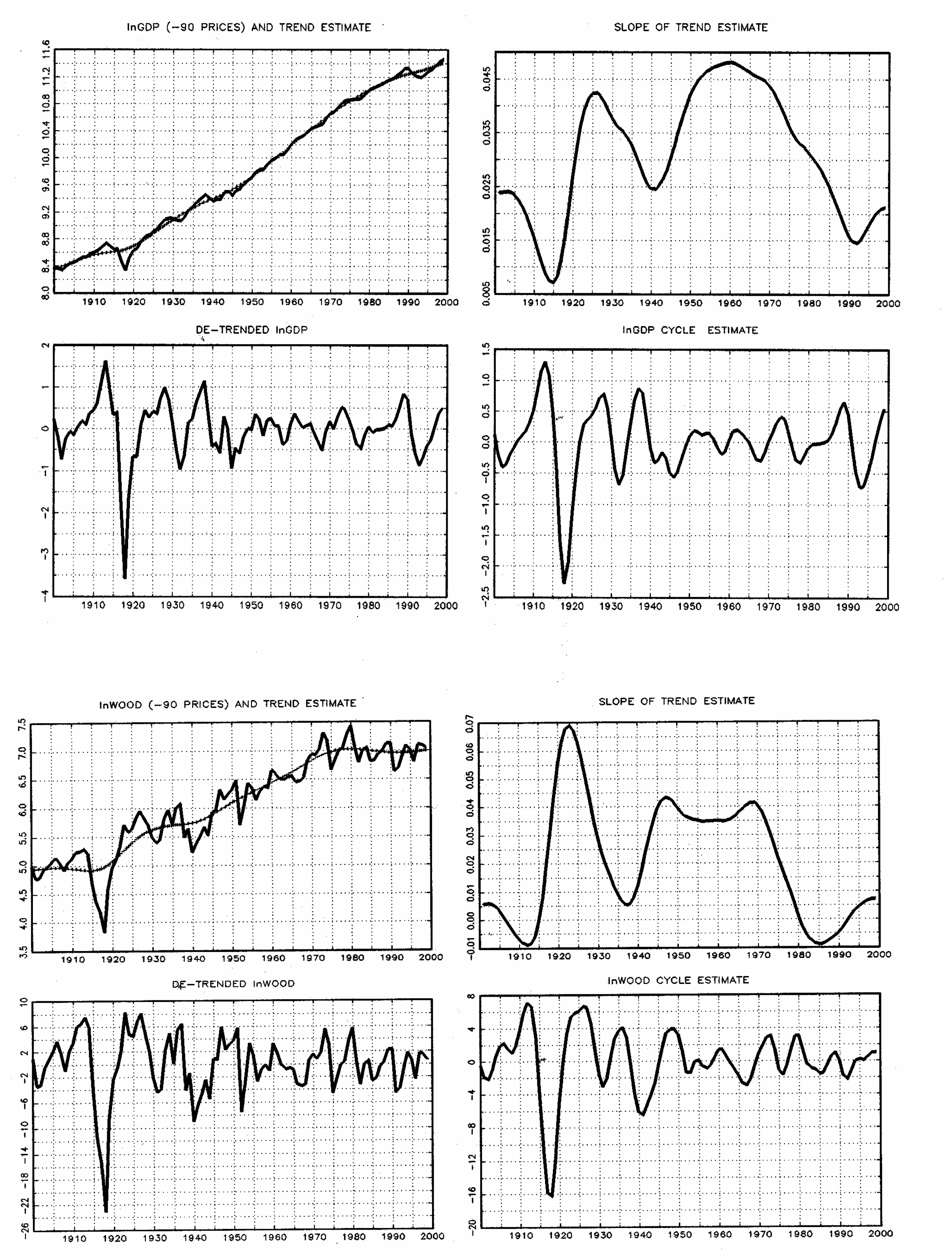
where d^2T/dt^2 is the second derivate of continuous cubic trend function $T(t)$ and λ controls the smoothness of trend fit. A small value of λ gives a non-smooth trend, and when $\lambda \to \infty$ there is a linear trend. In the spline model, the sum of squared deviations from trend function is minimized, subject to a roughness penalty. The approach is easy to program and to use compared to other smoothing techniques (e.g. Kalman filter).

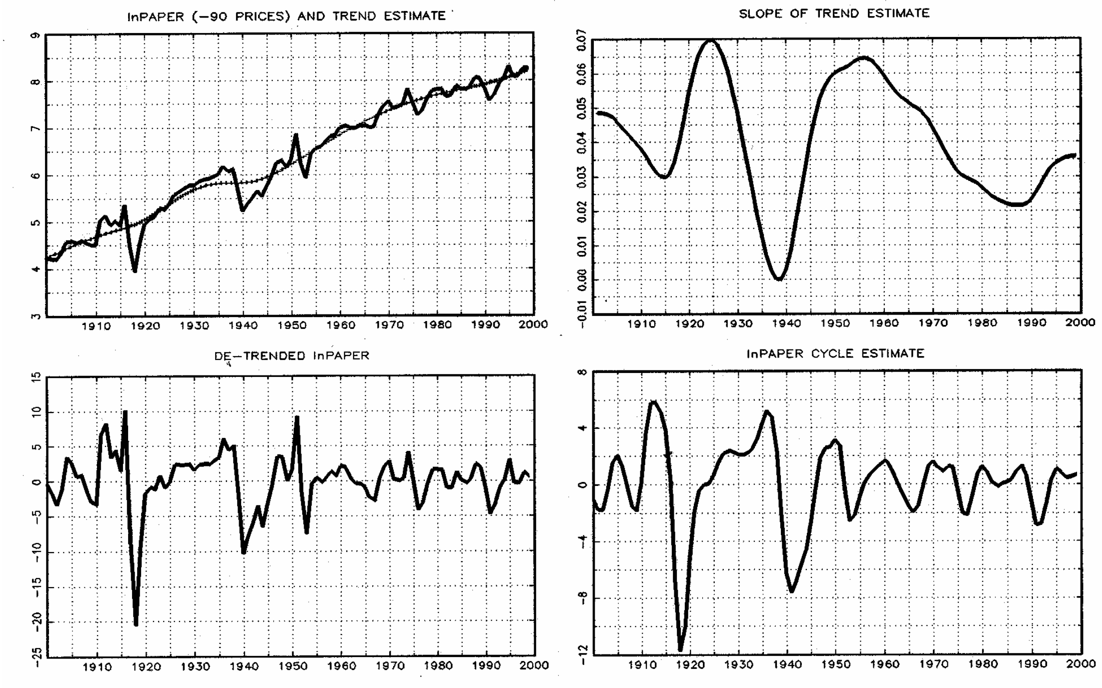
Thus, this method is applied first to the original series $X(t)$ and then to the de-trended series $C(t)=X(t)-\widehat{T}(t)$. Some methods exist to determine the optimal choice of the smoothing parameter λ, but in practice its value is often determined by visual inspection. In this context the improved AIC –method suggested by Hurvich et al (1998) was used to obtain the optimal $\boldsymbol{\lambda}$**.** Once the smooth cycle estimate $\widehat{C}(t)$ has been obtained, its stationary points $d\widehat{C}(t)/d(t)=0$ may be used to derive the turning-point dates of downturns and upswings. These dates enable the cycle length and magnitude to be derived.

These methods are applied to the following four series, depicted in Figure 2 and Figure 3 (GDP series)

GDP_t = gross domestic production at 1990 prices,
$WOOD_t$ = the output value of the wood-products industries at 1990 prices,
$PAPER_t$ = the output value of the pulp and paper industries at 1990 prices,
$FORESTRY_t$ = the output value of forestry at 1990 prices.

Figure 3. Trends and cycles for the series lnGDP$_t$, lnWOOD$_t$, lnPAPER$_t$ and lnFORESTRY$_t$

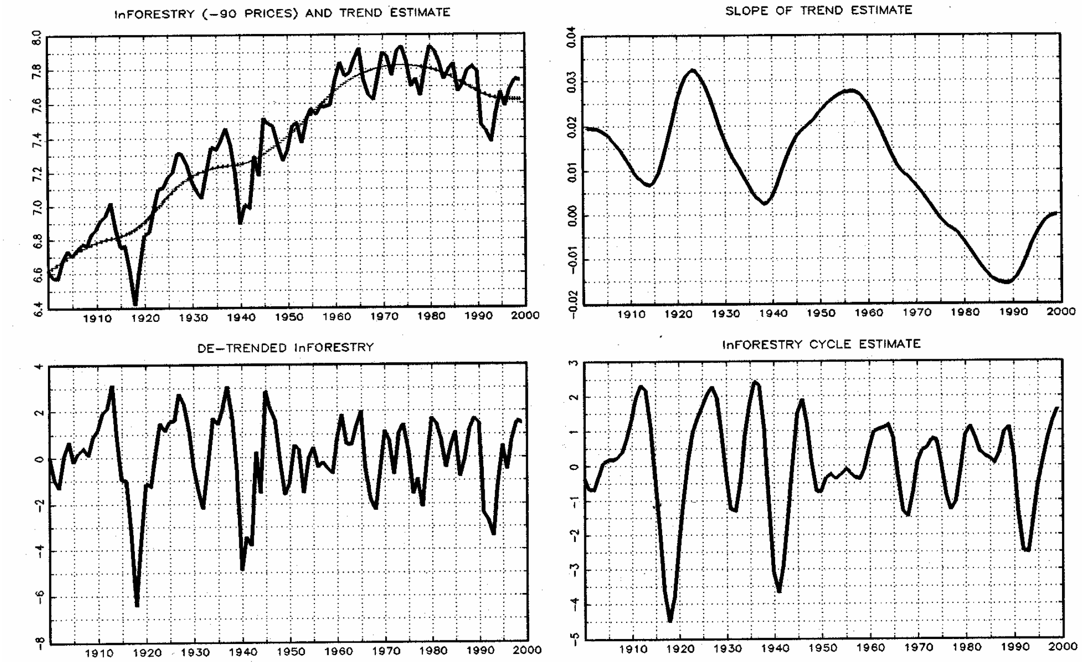



lnPAPER (−90 PRICES) AND TREND ESTIMATE

SLOPE OF TREND ESTIMATE

DE−TRENDED lnPAPER

lnPAPER CYCLE ESTIMATE


lnFORESTRY (−90 PRICES) AND TREND ESTIMATE

SLOPE OF TREND ESTIMATE

DE−TRENDED lnFORESTRY

lnFORESTRY CYCLE ESTIMATE

The GDP_t series is used here to give a general view of the growth path of the Finnish economy and its long-run relationship with the forest sector. It is a benchmark in terms of analysing the length and magnitude of cycles in the forest sector. Figure 3 gives the trend and cycle estimates for the series mentioned above. The trend-function estimates follow the idea that, in the long run (10-20 years), the average growth rate is stable. Changes in trends reflect the structural adjustments and changes in capital stock that take place in time periods of over 20 years. The slopes of the trend estimates reveal that large structural adjustments and changes took place in the forest sector in the years 1900-1940. Recovery from the Second World War was surprisingly fast. After the mid-1950’s there was a long, stable decrease (except in the wood-product sector) in the slopes of the trends until the end of the 1980’s, when new trend behaviour seems to start. Note that the GDP trend slope is always positive, and that the slope increase in the 1990’s occurred later than in the forest sector. The cycle estimates show that, in all cases, a deep downturn occurred in the late 1910’s, coinciding with the Finnish Civil War. The cyclical effect of the Second World War is not severe in the GDP series, which nevertheless did experience a deep recession in the 1990’s.

For the forest sector, the war years clearly had a halting effect on the output values, but the recession of the 1990’s was not as severe as in the GDP series. With respect to the war incidents last century, the corresponding possible cycles are treated with no difference in respect to other cycles. An alternative strategy would exclude them from the series or ignore them in the analysis. Since the prime focus here is not on the reasons behind the business cycles, an approach that enabled “war cycles” to be are included in the analysis was adopted. The analysis without them is not motivated since wars had observable effects on forestry and forest industry. The Figures show that the cyclical variability is much larger for the forest-sector series than for the GDP series. The vertical axes in the cycle-estimate figures measure their magnitude in percentages of output levels. The cyclical variability of the forest-sector series decreased in the latter part of the century but the number of cycles increased. Note also that the recession of the 1990’s shows up in the forest-industry series only as a regular downturn, while in the GDP series it corresponds well with the war-year downturns.

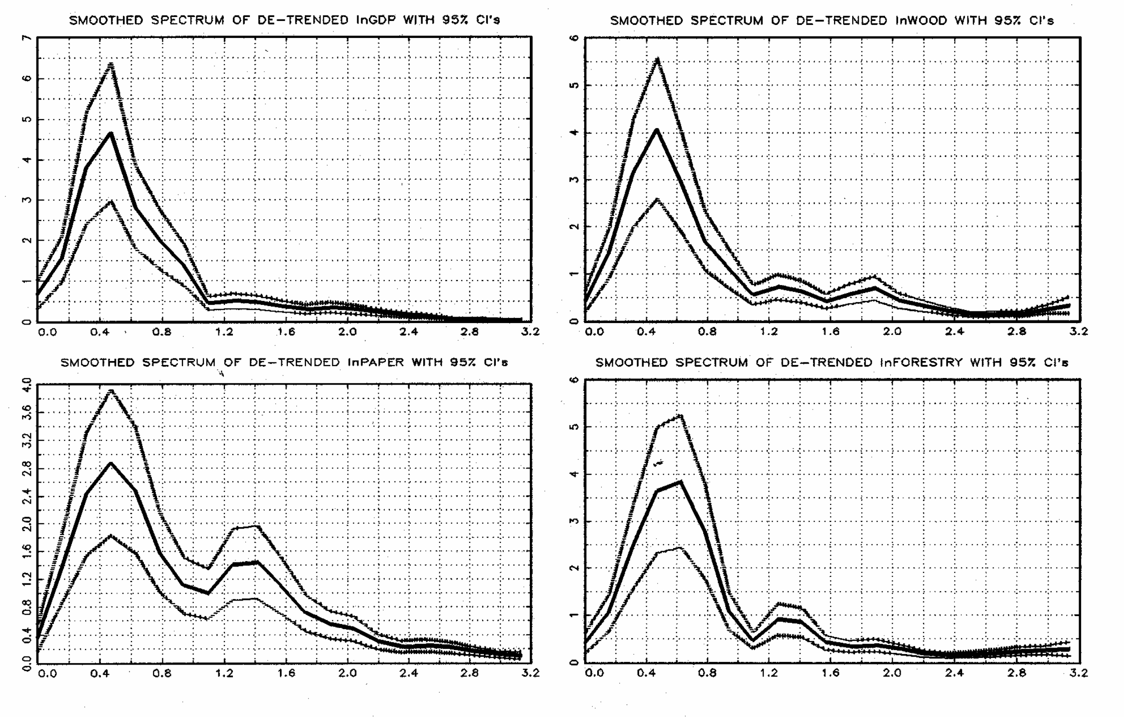
Table 1 gives the means and standard deviations of the cycle durations of the different series and the number of cycles. Note that, in this context, the cycles were measured in the following way: the upswing part is the length from trough to peak, while the downturn is the length from peak to trough. For all the series, the mean length of the economic booms is longer than that of the recessions. This asymmetry is typical in economic time series (see Linden 2001, Sichel 1993, Razzak 2001, Kontolemis 1997, Speight 1997). Likewise, the variability in downturn duration is smaller than in upswing duration. Table 1 and Figure 3 above indicate that the forest sector is more often hit by severe cycles than GDP. This means that the shock-propagation mechanism in the forest sector has some autonomous and independent patterns that are not found in the aggregate GDP series. It is interesting to note that the cyclical durations are shorter when the level of aggregation is low, i.e. durations are longer with GDP-series compared to forest sector series. The results may partly stem from the fact that aggregation induces some new dynamics to aggregate series comparated to the aggregated individual series (Linden 1999).

The outcome may also reflect the fact that forest sector has been one of the major export sectors of the Finnish economy. The international business cycles hit the forest sector more severe than the whole economy. The conducted exchange rate policy in Finland partly explains the fast adjustment process of forest sector. Many devaluations of Fmk in last century were targeted to restore the international competitive position of Finnish forest sector. In some cases (e.g. 1905-1910, 1950-1955 and 1975-1985) this has happened before the effects on GDP were realized . Note that during the period 1975-1985 the non-forest export sector of Finnish economy was closely related the Soviet economy with bilateral trade agreement. This stabilized the economy during this period.

Table 1. The number and summary statistics of cyclical durations of the lnGDP$_t$ and forest-sector output-value series, 1900-1999.

Series	*Number of upswings*	*Mean duration of upswings*	*Standard deviation of upswing durations*	*Number of downswings*	*Mean duration of downswings*	*Standard deviation of downswing durations*
lnGDP$_t$	11	5.45	3.26	10	3.60	1.43
lnWOOD$_t$	16	3.50	1.71	14	2.95	1.59
lnPAPER$_t$	16	3.55	2.10	15	2.70	1.29
lnFORESTRY$_t$	15	3.60	2.33	14	3.00	1.36

Figure 4. Spectrum estimates for the de-trended series lnGDPc$_t$, lnWOODc$_t$, lnPAPERc$_t$ and lnFORESTRYc$_t$



These features are also found in the spectral analysis. Spectral analysis gives the power (or mass) spectrum that shows how the total variability (or mass of variance) of the series is distributed over the frequency (Wei 1990). A smooth series has spectra with most of the power at low frequencies, while highly-oscillating series would show most of their power at high frequencies. Figure 4 gives the smoothed-power spectrum estimates with 95% confidence intervals for different de-trended series found in Figure 3. The Parzen lag window with 20 years is used for the smoothing. The spectrums have similar mass peaks at the frequency region 0.4-0.6, corresponding to a full-cycle period of 6-12 years. The spectrums for the pulp and paper and forestry sectors show small peak at frequency 1.2-1.6, giving a short period cycle with a length of 5-4 years. These estimates correspond closely to the average full-cycle length estimates found in Table 1. There exists hardly any studies consecrating on the business cycle durations at sectoral level. Most of studies report results with GDP series for USA and UK. The business cycle durations for these countries is somewhat shorter than for the Finland found in this study (see Diebold & Rudebusch 1999, Mudambi & Taylor 1995, Sichel 1991, Watson 1994). Linden (2001) reports that GDP cycles have been longer in Finland compared to Sweden in period 1950-2000.

The cycle coherence between the series is analysed next. By cycle coherence we mean the similarity of the cyclical patterns during a given time period. Table 2 gives the percentages of the years when the upswings and downswings in the two series coincide.

Table 2. The percentage (%) of years when upswings (U) and downswings (D) coincided in different series during the period 1900-1999 (period 1950-1999 in parenthesis)

	ln**WOODc$_t$**	**lnPAPERc$_t$**	**lnFORESTRYc$_t$**
lnGDPc$_t$	U: 43 (38) D: 32 (34)	U: 41 (38) D: 28 (24)	U: 47 (46) D: 32 (34)
lnWOODc$_t$		U: 43 (38) D: 35 (34)	U: 41 (36) D: 31 (30)
lnPAPERc$_t$			U: 42 (38) D: 32 (26)

The results indicate that cycle coherence was quite strong in the sample period. However coherence between the forest-sector series and between the GDP and the forest-sector series is similar although forest sectors are closely linked to each other.

The coherence is stronger in the upswings than with downswings. The findings shown in Table 2 imply that different series pairs act counter cyclically to each other every fourth year, on average. The series coherence was somewhat weaker in the latter half of the century than in the whole sample. However, it should be noted, that the figures are not informative concerning the predictive power of the series on each other.

4. Series dependencies

4.1. Granger non-causality

The forest sector constitutes a closely-linked cluster with raw-material suppliers (the forests owners) and wood-using industries. The structural adjustments in different sectors have their effects on other sectors. One sector may show adjustment paths that have lagged effects on other sectors. Economic time series analysis provide some effective methods to analyse the dynamic connections between different series (Mills 1992). Granger non-causality tests are often used in this context. The test idea is that if the past values of some series have no predictive power on some other series, a causal connection between the series hardly exists. The test is based on testing the parameter restrictions $\beta_{i,v} = 0$ for all lag values, $v = 1,...,p$ for all variable pairs, $i \neq j$ $(i, j = 1,2,..,N)$:

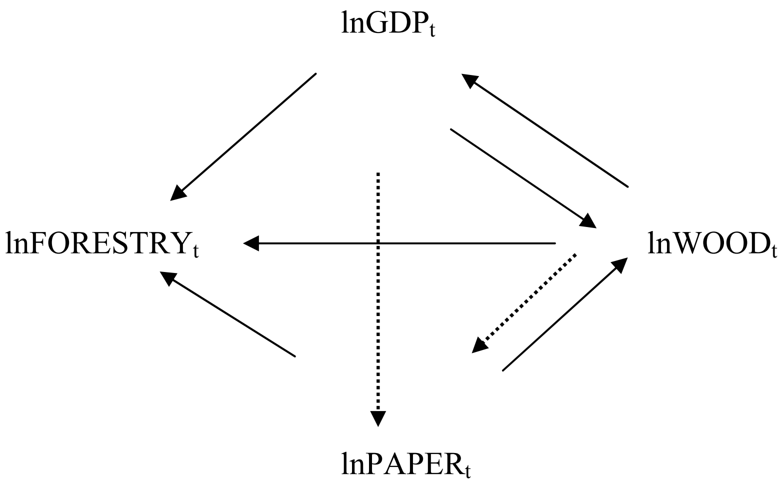
$$X_{i,t} = \sum_{v=1}^{p} \alpha_{i,v} X_{i,t-v} + \sum_{v=1}^{p} \beta_{i,v} X_{j,t-v} + \varepsilon_{i,t}.$$

The chosen lag value p is long enough to secure that model errors are non-correlated and normally distributed. The standard F-test is then valid for parameter restrictions.

Block non-causality tests use a vector autoregressive (VAR) form of the above equations in which the predictive power of some block of series is tested on the remaining block. Figure 5 gives the results of the pair-wise Granger non-causality testing. The exact test values are to be found in Appendix 1. As all the series are non-stationary unit-root series (see Appendix 2), the Granger non-causality tests are conducted in both level and difference forms $(\Delta \ln X_t)$ to avoid a trend effect on the test values. In the upper part of Figure 5, the solid arrows indicate test values in which both the level and the differenced series produce rejection of non-causality, and the non-solid arrows are based on a similar outcome only in the level-series testing. Only the non-causality results are given for the block tests.

The results of the Granger causality tests show that, in all the four series, only the lnGDP$_t$ series has some autonomy. The pulp and paper industry and forestry output series have low predictive power, but they are strongly predicted by the other series. These results indicate that shocks most often occur at the GDP level, and have effects on the forest sector. However, the dynamics in the wood-product industries seem to have some predictive power over the other series, including GDP.

Figure 5. The causal connections between the series. Pair-wise tests: causal cases



Block tests: non-causality cases

lnPAPER$_t$ does not predict 3 other series
lnFORESTRY$_t$ does not predict 3 other series

$\Delta\,\text{lnPAPER}_t$ does not predict 3 other series
$\Delta\,\text{lnFORESTRY}_t$ does not predict 3 other series
lnPAPER_t and lnFORESTRY_t do not predict 2 other series

4.2. Cointegration

In the long run economic time series may be connected to each other with complicated feed back rules although the series are non-stationary. A possibility exists that the series are linearly related to each other with stationary errors. The series are then cointegrated and their relationship show equilibrium or steady state behaviour.

The cointegration or common trend properties within the system of unit-root variables can be analysed using multivariate time series methods (see Maddala & Kim 1998). The Johansen method to derive the rank of cointegration matrix is built on a VAR framework treating all variables as endogenous. In this context, four variables give up to three separate co-integration or long-run solution vectors between the variables. The VAR(4) model with unrestricted constants was used as the starting point of the cointegration analysis. This alternative was not rejected in the preliminary testing with AICC model selection routine. The residuals of estimated VAR(4) model were also non-correlated and normally distributed. Table 3 gives the results of Johansen's co-integration (CI) estimation and testing procedure.

The results show that at least one cointegration vector exists among the series with a 10% or less critical test level. The exogeneity testing helps us to solve the long-run solution, i.e., to determine which variable parameter is used as a normalising factor. The tests show that the adjustment parameters for the variables lnGDP_t, lnPAPER_t and lnFOREST_t are zero in the model for lnWOOD_t. The value of the error-correction parameter for lnWOOD_t is –0.21. Thus it takes over 5 years to reach the steady-state solution after a shock has occurred in the dynamic model of the wood-products industry output value. The exogeneity test results indicate that it is not possible to derive a the long-run parameters for the forest industry sectors have the same signs.

Table 3. Cointegration results for the VAR(4) system with constants for the series $\ln GDP_t$, $\ln WOOD_t$, $\ln PAPER_t$ and $\ln FORESTRY_t$

Rank of CI matrix: H_0	*Rank of CI matrix: H_1*	*Eigenvalue test value*	*95% critical value*	*90% critical value*	*Trace test value*	*95% critical value*	*90% critical value*
Rank = 0	Rank = 1	25.85*	27.42	24.99	54.00**	48.88	45.70
Rank <=1	Rank = 2	16.19	21.12	19.02	28.14	31.55	28.78
Rank <=2	Rank = 3	11.93	14.88	12.98	11.95	17.86	15.76
Rank <=3	Rank = 4	0.014	8.07	6.50	0.014	8.07	0.014

Weak exogeneity testing for the adjustment-parameter vector under rank = 1 for the CI matrix

	$\ln GDP_t$ *H_0:* *$a_2=a_3=a_4=0$*	*$\ln WOOD_t$* *H_0:* *$a_1=a_3=a_4=0$*	*$\ln PAPER_t$* *H_0:* *$a_1=a_2=a_4=0$*	*$\ln FORESTRY_t$* *H_0:* *$a_1=a_2=a_3=0$*
LR-test for weak exogeneity (p-value)	8.09 (0.044*)	2.45 (0.483)	9.17 (0.027*)	10.02 (0.018*)

Normalized long-run solution vectors

	$\ln GDP_t$	*$\ln WOOD_t$*	*$\ln PAPER_t$*	*$\ln FORESTRY_t$*
Non exogeneity	-1.00	0.69	0.54	-0.38
Exogeneity	0.79	-1.00	-0.28	0.85

One interpretation of this is that, in the long run, the wood-products industry has been in a competitive position with the pulp and paper industry. Both have a positive effect on GDP, but a larger paper sector means a smaller wood-products industry in the industry model.

4.3. Cyclical dynamics

In order to get a more transparent picture of the occurrence of business cycles in the forest sector and the GDP series a VAR model and impulse-response analysis (IRA) was carried out on the de-trended series. The IRA makes it possible to detect how shocks in one of the equations of a four-variable system affects the future values of the variables. The IRA is more informative than Granger non-causality tests since we are able to analyse the adjustment paths of different series simultaneously. IRA is based on the moving-average (MA) presentation of the VAR system. For simplicity, let us consider a VAR(1) model in which X_t is a vector of stationary variables, A is a matrix of coefficients on lagged values of X_t, and ε_t is a vector of serially independent errors.

$$X_t = AX_{t-1} + \varepsilon_t$$

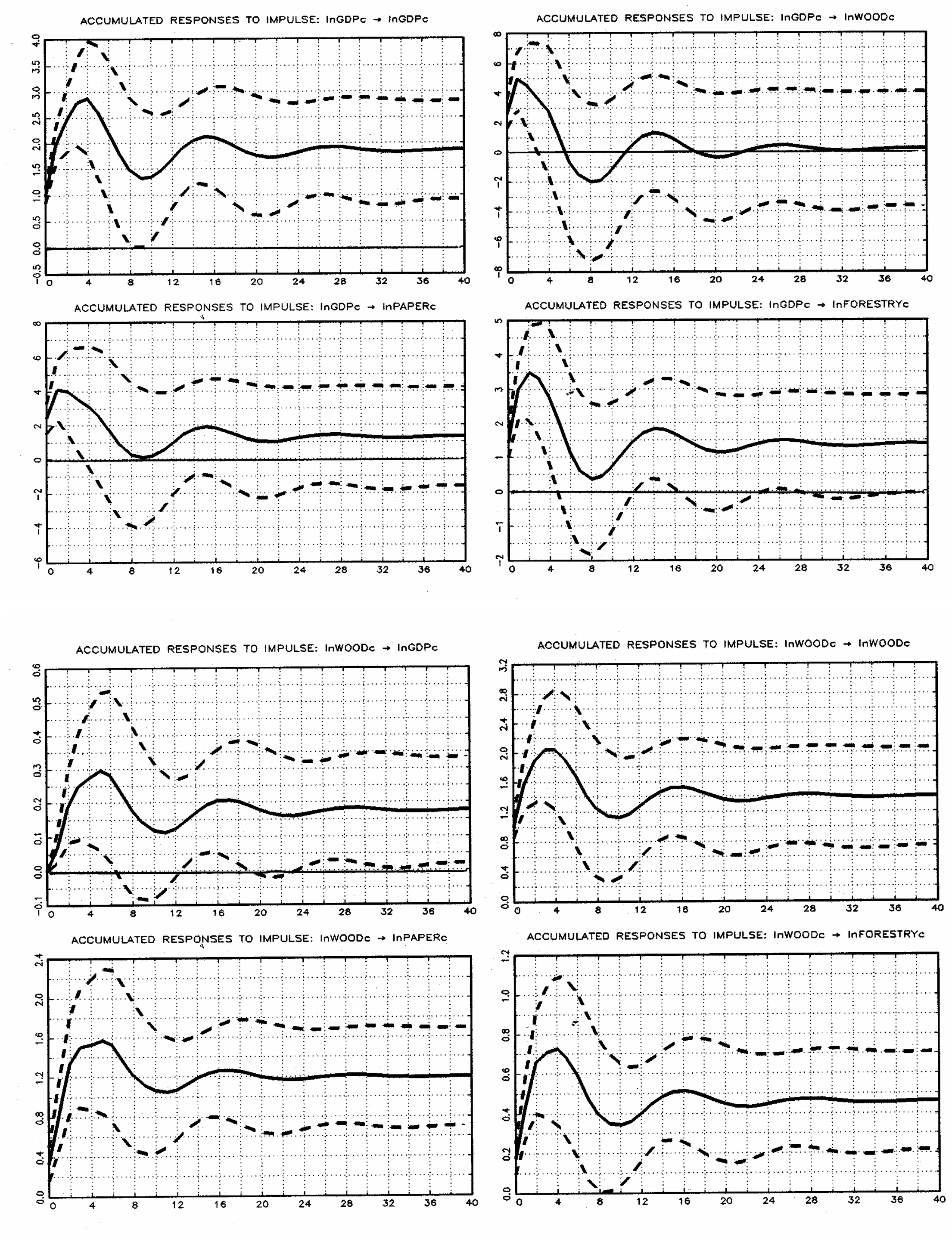
$$\Rightarrow \qquad X_t(I - AB) = \varepsilon_t \qquad (BX_t = X_{t-1})$$

$$\Rightarrow \qquad X_t = (I - AB)^{-1}\varepsilon_t = C(B)\varepsilon_t = \varepsilon_t + \sum_{v=1}^{\infty} C_v \varepsilon_{t-v} .$$

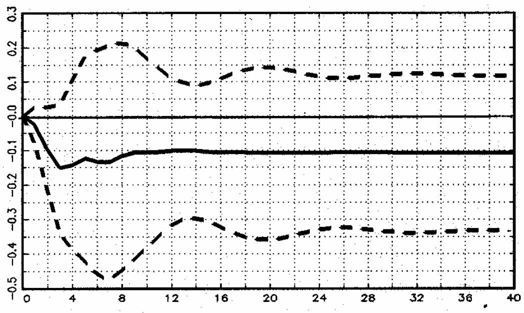
$C(B)$ is an infinite order-matrix polynomial that gives the impact of shocks on the value of X_t. The IRA simulation is conducted in the following way. An artificial shock in some past value of error in equation i, e.g. $\varepsilon_{i,t-p}$, takes the value of one and other errors take the value of zero. Its effect on future values of X_t is the calculated using impulse-response weights C_v, obtained by inverting the estimate of A.

Figures 6a-6d gives the accumulated impulse responses of one-unit orthogonal shocks in the errors of the VAR(4) model for the variables $\ln GDPc_t$, $\ln WOODc_t$, $\ln PAPERc_t$ and $\ln FORESTRYc_t$. Here, c refers to the de-trended cyclical series obtained in Section 2 above. Figure 6a gives the responses of shocks in $\ln GDPc_t$. The response time was set at 40 years. In the long run, a one-unit (1%) positive shock in GDP turns into a two unit (2%) accumulated GDP response in 40 years. The long-run behaviour is cyclical but tails off in 30 years. The forest-sector response effects are rather strong, but they lose their statistical significance very soon as the 95% confidence intervals contain null effects after 4-5 years. However, these short-run impulse-response effects are stronger

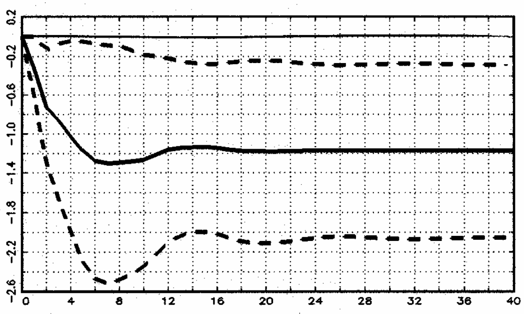
Figure 6. Accumulated impulse responses with 95% CIs for the lnGDPc$_t$, lnWOODc$_t$, lnPAPERc$_t$ and lnFORESTRYc$_t$ series



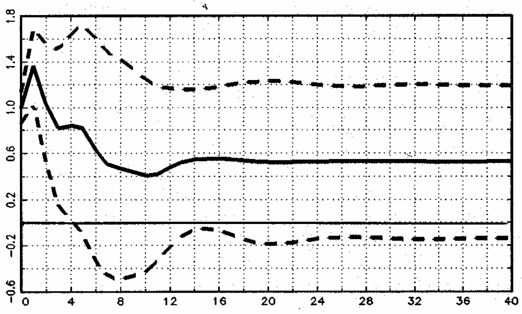
ACCUMULATED RESPONSES TO IMPULSE: lnPAPERc → lnGDPc



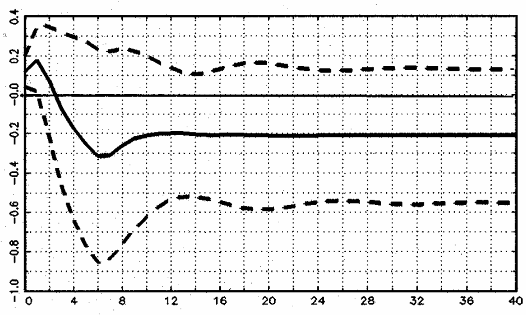
ACCUMULATED RESPONSES TO IMPULSE: lnPAPERc → lnWOODc



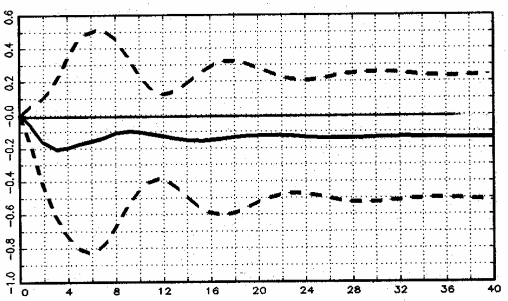
ACCUMULATED RESPONSES TO IMPULSE: lnPAPERc → lnPAPERc



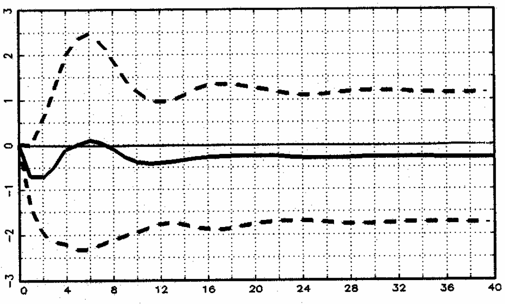
ACCUMULATED RESPONSES TO IMPULSE: lnPAPERc → lnFORESTRYc



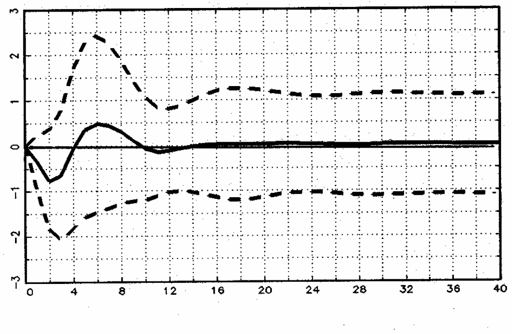
ACCUMULATED RESPONSES TO IMPULSE: lnFORESTRYc → lnGDPc



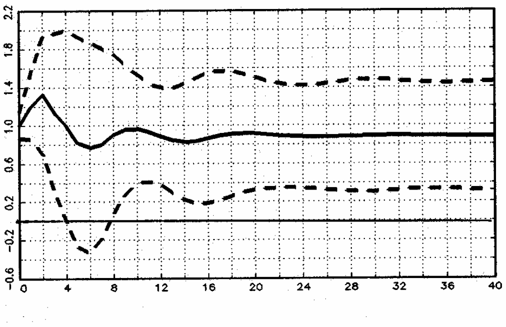
ACCUMULATED RESPONSES TO IMPULSE: lnFORESTRYc → lnWOODc



ACCUMULATED RESPONSES TO IMPULSE: lnFORESTRYc → lnPAPERc



ACCUMULATED RESPONSES TO IMPULSE:lnFORESTRYc → lnFORESTRYc



in the forest industries than in forestry, having point-estimate values close to 5 and 4 units. The results speak for Keynesian types of multiplier effects, but the forest-sector effects are shorter than one would expect.

As Figure 6b shows, a unit shock in the wood-producing industries has surprisingly large effects on GDP and the remaining forest sector. The maximum accumulated GDP effect is reached in 5 years at the 0.3% level. After 7 years, the effects are rather uncertain, stabilising at the 0.18% level in the long-run. The large GDP effects reflect the historical fact that in the first part of the 20th century, the wood-products industry was one of the most important sectors in the Finnish economy. Figure 6b shows the forest-sector effects that are significant for the whole forecasting period. The responses in different branches of the forest-sector are closely linked to each other.

However a 1% shock in the wood-products sector only produced an additional 0.4% sector effect in the long run. The response effects are much larger in the pulp and paper sector (1.2%), while for forestry-sector effect is 0.45%. The sectoral effects are clearly cyclical.

Figure 6c gives the IRA of output-value shock in the pulp and paper sector. The effects have statistical significance only for very short periods for the pulp and paper industry itself, and for the forestry industry. However, they are strong, negative and lasting for the wood-products sector. Thus this provides additional evidence of offsetting behaviour between the two forest industries. Figure 6d gives the forestry-impulse effects, which have some significance for only 4 years. This result was expected since the forestry sector had no predictive power on other sectors in the GC analysis (see Figure 5 above).

5. Conclusions

The Finnish forest-sector long-run series augmented with GDP series from the 20th century constitute an important source in studying the evolution of the Finnish economy. The trend and cyclical features of the yearly observations from 1900 until 1999 were analysed using different methods. The first part of the paper focused on the trend and cycle estimates of GDP, and on the output-value series of the forest sector. The latter part consists of analyses of series dependency.

The forest sector was a key sector in the Finnish economy at the beginning of the last century. Since then its importance has decreased. A major structural change started in the early 1950's when the output value of the pulp and paper industries started to grow rapidly, and the growth pace slowed down, or even started to decrease, for other forest-sector branches. The trend slopes in all four series contain large swings in the pre-1950 period, but after that there was a declining trend growth period until the early 1990's.

The business cycles were also larger in the first half of the century than in the second half. The forest sector cycles were shorter than the GDP cycles although the cycle coherence was high between all of the output-value series. The forest series contained short period cycles that were not found in the GDP series. Granger non-causality tests showed that it was only the GDP series that had predictive power over all the other series. The wood-products output series was an exception to this rule, as it could also predict the GDP series. The output value of forestry was determined by the other sectors and it had no predictive power over the other series.

However, the long-run analysis conducted using co-integration methods implied that one co-integration vector existed between the four series. The output value of the wood-products industry was weakly exogenously determined by GDP and by the other forest sectors. Cycle dynamics were derived using impulse-response analysis (IRA). The GDP shock effect was well detected in all the other series, although the duration was short. The wood-industry effects were most permanent among the sector-level shocks.

The results obtained in this study is most easily understood with the Keynesian type two sector model of business cycles described in the section 2. Although sector 2 (the forest sector) has experienced some autonomous cyclical movements not found in the other sectors of economy, the shocks in forest sector detect mainly from the aggregate economy. However the latter is not affected seriously by forest sector. The impulse response figures for shocks in de-trended series indicate that second order difference equation model with parameters giving stable complex roots is a suitable alternative for the series. However the cyclical features in series are found above to be asymmetrical and aperiodic. This means that some non-linear and the chaotic modelling alternative would be more realistic alternative in this context. At this moment the experience of estimation and testing of two sector non-linear models is very limited. The approach of stochastic linear difference equations may still be valid as we can always hide minor non-linearities in random part of model.

Generally the results showed some basic economic growth results of the Finnish forest sector in the years 1900-1999. Any connections to the international business cycles or conducted economic policy in Finland (e.g. exchange rate policy) were not analysed. The future research will give us more detailed picture of the structural change and adjustment path of the Finnish forest sector in the international framework.

References

Benhabib, J. & Nishimura, K. (1979) "The Hopf Bifurcation and the Existence and Stability of closed orbits in Multisector Models of Optimal Economic Growth*",* *Journal Economic Theory,* Vol. 35, 145-170.

Benhabib, J. & Nishimura, K. (1985) "Competitive Equilbrium Cycles", *Journal Economic Theory,* Vol. 45, 284-306.

Boldrin, M. (1986) "Paths of Optimal Accumulation in Two-Sector Models", in Barnett. W., Geweke,J. & Shell, K. eds. *Economic Complexity: Chaos, Sunspots, Bubbles and Nonlinearity*, 231-252, Cambridge University Press. Cambridge.

Boldrin, M. & Deneckere, R.J. (1990) "Sources of Complex Dynamics in Two-Sector Growth Models", *Journal of Economic Dynamics and Control*, Vol. 14, 627-53.

Boldrin, M. & Woodford, M. (1992) "Equilibrium Models Displaying Endogenous Fluctations and Chaos: A Survey", in Benhabib. J. ed. *Cycles and Chaos in Economic Equilibrium*, p. 8-43*,* Princeton University Press. Princeton

Diebold, F.X. & Rudebusch, G.D. (1999) *Business Cycles. Durations, Dynamics, and Forecasting*, Princeton University Press. Princeton.

Dore, M.H.I. (1993) *The Macroeconomics of Business Cycles. A Comparative Evaluation,* Blackwell. London.

Eltis, W. (1984) *The Classical Theory of Economic Growth*, Macmillan Press. London.

Fatas, A. (2000) "Endogenous Growth and Stochastic Trends, *Journal of Monetary Economics*, Vol. 45, 107-128.

Gabisch, G. & Lorenz, H.-W. (1987) *Business Cycle Theory*, Springer-Verlag. Berlin.

Gomez, V. (1999) "Three equivalent methods for fitting finite nonstationary time series", *Journal of Business and Economic Statistics*, Vol. 17, 109-115.

Goodwin, R.M. (1951) "The Non-linear Accelerator and the Persistence of Business Cycles", *Econometrica*, Vol. 19, 1-17.

Green, P.J. & Silverman B. (1994*) Nonparametric Regression and Generalized Linear Models*, Chapman & Hall. London.

Gregory, A.L., Head, A.C. & Raynald, J. (1997) Measuring World Business Cycles", *International Economic Review*, Vol. 38, 677-701.

Harvey, A.C. & Jaeger, A. (1993) Detrending, stylized facts and the business cycles", *Journal of Applied Econometrics*, Vol. 8, 231-47.

Hicks, J.R. (1950) *A Contribution to the Theory of the Trade Cycle.* Oxford University Press, Oxford.

Horvath, M. (2000) "Sectoral Shocks and Aggregate Fluctations", *Journal of Monetary Economics*, Vol. 45, 69-106.

Hurvich,C.M., Simonoff, F.S. & Tsai, C.-L. (1998) Smoothing Parameter Selection in Nonparametric Regression Using an Improved Akaike Information Criterion, *Journal of Royal Statistical Society*, Series B, Vol. 60, 271-293.

Inada, K. (1964) "On the Stability of Growth Equilibria in Two-Sector Models", *Review of Economic Studies,* Vol. 31, 127-142.

Jarsulic, M. (1993) "Recent Developments in Business Cycle Theory", *Review of Political Economy*, Vol. 5, 344-364.

Kontolemis, Z.G. (1997) "Does Growth Vary over the Business Cycle? Some Evidence from the G7 Countries", *Economica*, Vol. 64, 4431-60.

Linden, M. (1999) "Time Series Properties of Aggregated AR(1) Proocesses with Uniformly Distrubuted Coefficients", Economic Letters, Vol. 64, 31-36.

Linden, M. (2001**)** Trendikasvu ja suhdannesyklit Suomessa ja Ruotsissa 1950-2000 (Trend Growth and Cycles in Finland and Sweden 1950-2000*), Kansantaloudellinen Aikakauskirja, Vol. 97/2, 249-263.*

Maddala, G.S. & Kim. I.-M. (1998) *Unit Roots, Cointegration, and Structural Change,* Cambridge University Press, Cambrige.

Matsuyama, K. (1999) "Growing Through Cycles", *Econometrica*, Vol. 67, 335-347.

Mills, T.C. (1993) *Time Series Techniques for Economist*, Cambridge University Press, Cambrige.

Montrucchio, L. (1992) Dynamic Systems that Solve Continuous-Time Concave Optimization Problems: Anything Goes, ", in Benhabib. J. ed. *Cycles and Chaos in Economic Equilibrium*, p. 277-288, Princeton University Press. Princeton.

Mudambi, R. & Taylor, L.W. (1995) "Some Non-Parametric Test for Duration Dependence: An Application to UK Business Cycle Data", *Journal of Applied Statistics*, Vol. 22, 163-177.

Mullineux, A. & Peng, W. (1993) "Nonlinaer Business Cycle Modelling", *Journal of Economic Surveys*, Voll. 7, 41-83.

Nishimura, K. & Yano, M. (1995) "Nonlinear Dynamics and Chaos in Optimal Growth: An Example", *Econometrica*, Vol. 63, 981-1001.

Ramanathan. R. (1982) *Introduction to the Theory of Economic Growth*, Springer-Verlag. Berlin.

Razzak, W.A. (2001) "Business Cycle Asymmetries: International Evidence", *Review of Economic Dynamics*, Vol. 4, 230-243.

Samuelson, P.A. (1939) "Interactions Between the Multiplier Analysis and Principle of Acceleration" *Review of Economic Studies,* Vol. 21, 75-78.

Sato, Y. (1985) "Marx-Goodwin Grwoth Cycles in a Two-Sector Economy", *Journal of Economics*, Vol. 45, 21-34.

Sichel, D.E. (1991) "Business Cycle Duration Dependence: A Parametric Approach", *Review of Economics and Statistics*, Vol. 73, 254-260.

Sichel, D. (1993) "Business cycle asymmetry: A deeper look", *Economic Inquiry*, Vol. 31, 224-236.

Speight, A.E.H. (1997) "Testing for Business Cycle Asymmetry: Some International Evidence", *Applied Economics Letters*, Vol. 4, 603-606.

Uzawa, H. (1963) "On the Two Sector Model of Economic Growth II", *Review of Economic Studies,* Vol. 30, 105-118.

Watson, M.W. (1994) " Business-Cycle Durations and Postwar Stabilization of the U.S. Economy", *American Economic Review*, Vol. 84, 24-46.

Wei, W.W.S. (1990) *Time Series Analysis: Univariate and Multivariate Methods*, Addison Wesley, New York

Woitek, U. (1997) *Business Cycles. An International Comparison of Stylized Facts in a Historical Perspective* , Physica-Verlag. Heidelberg.

Appendix 1. Granger non-causality tests for the $\ln GDP_t$, $\ln WOOD_t$, $\ln PAPER_t$ and $\ln FORESTRY_t$ series.

$series$	$F - test$
$\ln GDP_t \to \ln WOOD_t$	$F(2,93) = 6.37*$
$\ln GDP_t \to \ln PAPER_t$	$F(2,93) = 9.65*$
$\ln GDP_t \to \ln FORESTRY_t$	$F(2,93) = 5.68*$
$\ln WOOD_t \to \ln GDP_t$	$F(2,93) = 4.23*$
$\ln WOOD_t \to \ln PAPER_t$	$F(2,93) = 6.97*$
$\ln WOOD_t \to \ln FORESTRY_t$	$F(2,93) = 9.41*$
$\ln PAPER_t \to \ln GDP_t$	$F(2,93) = 0.50$
$\ln PAPER_t \to \ln WOOD_t$	$F(5,84) = 2.74*$
$\ln PAPER_t \to \ln FORESTRY_t$	$F(2,93) = 3.42*$
$\ln FORESTRY_t \to \ln GDP_t$	$F(2,93) = 0.24$
$\ln FORESTRY_t \to \ln WOOD_t$	$(F(2,93) = 2.32$
$\ln FORESTRY_t \to \ln PAPER_t$	$F(2,93) = 0.07$

$series$	$F - test$
$\Delta \ln GDP_t \to \Delta \ln WOOD_t$	$F(2,92) = 4.13*$
$\Delta \ln GDP_t \to \Delta \ln PAPER_t$	$F(2,92) = 0.72$
$\Delta \ln GDP_t \to \Delta \ln FORESTRY_t$	$F(2,92) = 4.61*$
$\Delta \ln WOOD_t \to \Delta \ln GDP_t$	$F(2,93) = 6.97*$
$\Delta \ln WOOD_t \to \Delta \ln PAPER_t$	$F(2,92) = 9.74*$
$\Delta \ln WOOD_t \to \Delta \ln FORESTRY_t$	$F(2,93) = 8.21*$
$\Delta \ln PAPER_t \to \Delta \ln GDP_t$	$F(2,92) = 0.71$
$\Delta \ln PAPER_t \to \Delta \ln WOOD_t$	$F(2,92) = 1.91$
$\Delta \ln PAPER_t \to \Delta \ln FORESTRY_t$	$F(2,92) = 3.48*$
$\Delta \ln FORESTRY_t \to \Delta \ln GDP_t$	$F(2,92) = 0.32$
$\Delta \ln FORESTRY_t \to \Delta \ln WOOD_t$	$(F(2,93) = 1.18$
$\Delta \ln FORESTRY_t \to \Delta \ln PAPER_t$	$F(2,92) = 0.26$

Appendix 2. ADF tests

Augmented Dickey-Fuller unit root test is based on the following regression model

$$x_t = a + bt + cx_{t-1} + \varepsilon_t \qquad \Rightarrow \qquad \Delta x_t = a + bt + (c-1)x_{t-1} + \varepsilon_t$$

where $H_0 : c = 1$ and $\varepsilon_t \sim NID(0, \sigma^2)$. If errors are autocorrelated we use regression $\Delta x_t = a + bt + (c-1)x_{t-1} + \sum_{i=1}^{p} d_i \Delta x_{t-i} + \varepsilon_t$ to obtain non-correlated case. The t-statistics of OLS estimate for $v = c - 1$ is used for the testing. The distribution of the statistics is non-standard.

ADF tests: Trend and constant included

$series$	$t-value$	p	$p-value\ of\ lag$
$\ln GDP_t$	-2.42	4	0.001
$\ln WOOD_t$	$-3.64*$	0	
$\ln PAPER_t$	-3.41	2	0.02
$\ln FORESTRY_t$	-2.77	0	

5% critical value: -3.46

ADF tests: Constant included

$series$	$t-value$	p	$p-value\ of\ lag$
$\ln GDP_t$	0.14	4	0.002
$\ln WOOD_t$	-0.99	5	0.005
$\ln PAPER_t$	-0.77	2	0.004
$\ln FORESTRY_t$	-1.89	0	

5% critical valus:=-2.89

ADF tests: Constant included

$series$	$t-value$	p	$p-value\ of\ lag$
$\Delta \ln GDP_t$	$-6.075*$	4	0.004
$\Delta \ln WOOD_t$	$-5.77*$	3	0.017
$\Delta \ln PAPER_t$	$-10.09*$	1	0.001
$\Delta \ln FORESTRY_t$	$-9.05*$	0	

5% critical valus:=-2.89