Growth Theories and the Persistence of Output Fluctuations: The Case of Austria

GROWTH THEORIES AND THE PERSISTENCE OF OUTPUT FLUCTUATIONS: THE CASE OF AUSTRIA

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Abstract: The paper analyses the degree of output persistence in GDP in order to empirically discriminate between the Solow growth model, the perfect competition endogenous growth model, the imperfect competition endogenous growth model, and the subcase of a multiple equilibria model of endogenous growth for the case of Austria. We find that a temporary shock in the growth rate of output induces a permanent and larger effect on the level of GDP. This leads us to refute the Solow growth model and the perfect competition model. We find strong empirical support for the imperfect competition growth model, but cannot fully rule out the possibility of multiple equilibria growth rates.

Keywords*:* Austria, output persistence, endogenous growth, univariate time series analysis

JEL codes: C22, O47, O52

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I. Motivation

This paper investigates output persistence in Austria in order to identify the appropriate growth model for the Austrian economy.

In the traditional view, movements in output are divided into a deterministic long-run growth component and stochastic cyclical fluctuations around that trend. Whilst business cycle theory has focused exclusively on the explanation of short-run fluctuations, growth theory has focused on long-run behaviour. Recent developments have served to weaken this separation, but it is still present in the „benchmark"-models of modern macroeconomic theory: 'real business cycle theory' and the Solow-growth model.

'Real business cycle theory' is the currently dominating theory of short-run fluctuations in output and states that they are driven by stochastic arrivals of exogenous productivity changes (e.g. Kydland and Prescott 1982). In these models temporary stochastic shocks only cause temporary deviations from potential output. Given on average positive productivity gains, trend growth itself is stochastic but remains exogenous. While the fluctuations around average movements in productivity can be interpreted as the business cycle, movements in trend itself remain unexplained within the 'theory of real business cycles'. By contrast, traditional growth theory (e.g. Solow 1956) attempts to explain movements in trend, ignoring cyclical fluctuations. In the Solow model changes in trend are attributed to exogenous technical change.

The 'new growth theory' attempts to explain economic mechanisms that lead to changes in technology itself. A first wave of perfect competition models (e.g. Romer 1986 and Lucas 1988) stressed the importance of external effects in human capital accumulation, leading to nondecreasing returns in accumulative factors of production. A second wave of papers stressed the importance of innovative activity in imperfectly competitive markets (Romer 1990). Innovations are based on an economic rational, stating that innovations are undertaken as long as the present value of expected returns equals development costs. Hence in both models the path of long-run development of an economy becomes endogenous. Permanent changes in economic parameters can now alter the economic rate of growth permanently, whilst temporary shocks only induce level shifts.

Azariades and Drazen (1990), were amongst the first to note that with the presence of multiple equilibria in a new growth model at least large temporary shocks can move the economy to an equilibrium with a different rate of economic growth. However, large shocks are rare and should be easily identifiable. In a recent article Evans, Honkapohja and Romer (1998) argue that any change in economic parameters may lead to the same result in a monpolistic competition growth model with complementarities. When learning of agents about the economic model drives economic expectations, even a small and temporary change in parameters may lead to a convergence path towards a different equilibrium with different growth rates. As minor shocks hit the economy rather frequently, a reoccurring shift between equilibria is likely. So, the novel feature of Evans, Honkapohja and Romer is that temporary shocks to output can lead to a switching between equilibria of different growth rates. One may, in accordance with the authors, interpret this phenomenon as a strong persistence effect of business cycle fluctuations. In fact, their model represents the most recent attempt to reintegrate business cycle and growth theory to one comprehensive theory of output determination.

Given the diversity of theoretical models, it is important to discriminate between them empirically in order to specify the best fitting growth model for the Austrian economy. The question arises on which grounds the models are theoretically distinct, and whether we can exploit the distinction empirically.

The following chapter develops theoretical implications of the competing theories, and derives testable, competing hypotheses on the effects of transitory shocks on the growth rate of output, and contrasts the result with existing empirical literature. These hypotheses will be tested for Austrian data using univariate time series analysis. After describing the time series, and the presentation of the according ARIMA-process selection, we present the regression results, impulse response functions and the results of our hypotheses tests. We finish the paper with concluding remarks.

II. Discriminating Between the Theories

The above mentioned models yield distinct predictions on the reaction of changes in output with respect to temporary shocks to the growth rate of output. Let us be specific with the following example. Typically fluctuations in output are largely driven by changes in investment. An increase in investment is equivalent to a permanent endowment of additional physical capital to the economy. In the Solow model the marginal product of capital declines, leading to a reduction of gross investment in subsequent periods, which reduces the rate of economic growth until the initial level of output is reached. Hence the initial shock leads to an immediate increase in the growth rate of the economy. Thereafter, we will observe declining rates of growth, until the growth rate is at its pre-shock value.

By contrast, in the perfect competition model, an initial shift in the level of output does not deteriorate the marginal product of capital. Hence the economic incentives remain unchanged, but the productive capacity of the economy is increased once and for all. There is a permanent shift in the level of output equivalent to the effect of the initial factor endowment, but after the shock, the growth rate remains unaffected. Matsuyama (1995) was the first to note that the innovation driven monopolistic competition growth models inherently contain an investment multiplier, leading to a permanent shift in the level of output exceeding the effect of the initial factor endowment. Given that the adjustment exhibits inertia, we would observe an additional growth effect beyond the initial shock.

The multiple equilibria models represent a subgroup of monopolistic competition growth models, with a destinct prediction, however. One could expect a switch towards a new equilibrium, resulting in frequent switching between growth rates of the economy. For the empirical analysis we want to exploit the different degrees of output persistence as the discriminating factor between the theories.

The subject has in some respect already been investigated in the literature, and several studies on certain aspects of the preceding problem have already been conducted. Campbell and Mankiw (1987) were amongst the first to report permanent effects on the level of GDP from transitory shocks to output growth, first for the US and lateron for a selected sample of various countries (Campbell and Mankiw 1989). They do not find long-run persistence of growth rates, yielding support for the results of the Romer (1990) model. The Campbell and Mankiw results are challenged by Pischke (1991) for the United States and Demery and Duck (1992) for Canada, Germany, Italy, Japan, the

UK and the US. They show that including a structural break in 1973 in the time series model, as first outlined in Perron (1990 and 1993), heavily reduces the measure of persistence in output. The question arises whether these structural breaks are endogenous or exogenous. In the latter, this would point towards the results of the Solow model. If structural breaks indicate an endogenous switching between two different equilibrium growth rates, the result points towards the multiple equilibira model.

Several tests of time series properties have been conducted for Austrian time series. Url and Wehinger (1990) have tested different series for stationarity, including GDP, finding that output exhibits a stochastic rather than a deterministic trend, but their results do not allow to conclude whether permanent level effects of transitory shocks to output exist. Rünstler (1994) finds persistence in output following various foreign shocks in a structural vector autoregression model, however.

III. Test Procedure and Data

We investigate the persistence properties of the output series by applying a univariate time series process to the data. Confirming the results of Url and Wehinger (1990), we find that Austrian GDP is difference stationary, reducing the set of admissible processes to ARIMA(p, 1, q), equivalent to an ARMA(p, q)-process for the time series in first differences. The estimation results corresponding to the predictions of the models should yield negative autocorrelation for the Solow and 'real business cycle' models, no autocorrelation for the perfect competition model, under the sensible assumption of a noninstantenous investment multiplier positive autocorrelation for the imperfect competition model, and a random walk of growth rates for the multiple equilibria models. A general ARMA(p, q)-process for the growth rate of output, y_t,

$$A(L)\, y_t = M(L)\, e_t,$$

where $A(L)$ is the autoregressive lag polynomial, $M(L)$ is the moving average lag polynomial, and e_t is an i.i.d. random variable, may be transformed into an infinite moving average process of the following type,

$$y_t = [M(L)/A(L)]\ e_t.$$

Given the above general ARMA representation, it is possible to derive the additional long-run effect induced by a unit shock, as shown in the appendix, yielding,

$$\lim_{t\to\infty} y_t - 1 = \frac{\sum_{j=1}^{q} m_j + \sum_{i=1}^{p} a_i}{1 - \sum_{i=1}^{p} a_i},$$

where a_i is the autocorrelation coefficient of order i and m_j is the moving average coefficient of order j. The expression is finite unless the sum of autoregressive coeffecients is unity, which has been ruled out by stationarity tests. Indeed, test statistics turn problematic as the denominator approaches unity. The proceeding expression explains the additional long-run impact of any shock to output, hence we may formulate the following three test hypotheses,

$$\left| \frac{\sum_{j=1}^{q} m_j + \sum_{i=1}^{p} a_i}{1 - \sum_{i=1}^{p} a_i} \right| \begin{cases} < 0 \ldots H_0^{s} \\ = 0 \ldots H_0^{pc} \\ > 0 \ldots H_0^{ic} \end{cases},$$

where H_o^s is the null hypothesis for accepting the Solow model, H_o^{pc} is the null hypothesis for accepting the perfect competition endogenous growth model, and H_o^{ic} is the null hypothesis for accepting the imperfect competition endogenous growth model. As the statistical probability for the denominator to be exactly zero is null, and given precceding tests for stationarity of the series, we may, without loss of generality, ignore the denominator and use the numerator only to test the hypotheses. These three hypotheses allow us to explicitly test all but the multiple equlibria explanations of economic growth, which will be seperately discussed towards the end of chapter five.

For the estimation we use Austrian nominal GDP data in domestic currency from 1960 to 1995 provided by the Austrian Statistical Agency (ÖSTAT). We have terminated in 1995 in order not to conflict with the new European System of National Accounts data which are only computed back until 1976. We have deflated the series by a chained GDP Deflator (1986 = 100). The series has been linked twice, first in 1976, using the previous version of the GDP Deflator, and then in 1964, using the GNP Deflator, as no GDP deflator has been reported until 1964. All data have been taken from the same source as the nominal GDP series (WIFO, 1998). We have set a dummy variable in 1975 to correct for the first oil price shock, as this shock was an extreme and singular event. The logged time series is difference stationary, as tested with the augmented Dickey-Fuller and the Phillips-Perron test procedure.

IV. ARMA Process Selection and Estimation Results

In this chapter, we explore the statistical properties of various ARMA specifications, fitted to our series. The aim is to provide a specific model, which exhibits the best fit to the data. In order to find the optimal ARMA-specification we use the Akaike and Schwartz-criterion, which are both based on the value of the likelihood function (Judge et al, 1988, p. 768f.). Table I below provides the results. We have listed the maximal number of AR coefficients by line and the maximal number of MA coefficients by column.

Table I. Values of the Akaike and Schwartz criterion for estimated ARMA-processes

AR\MA	0	1	2	3	4	5
0	-7.888812	***-8.047182***	-8.028799	-8.172297	-8.195971	-8.230938
	-7.802623	***-7.917899***	-7.856421	-7.956825	-7.937405	-7.929278
1	-8.009889	-7.998999	-7.998302	-8.203662	-8.183393	-8.181758
	-7.880606	-7.826622	-7.782830	-7.945095	-7.881732	-7.837003
2	-7.975444	-8.091550	***-8.093450***	-8.168764	-8.183393	-8.215512
	-7.803067	-7.876078	-7.834884	-7.867103	-7.881732	-7.827662
3	-8.150065	-8.098981	-8.214079	***-8.262834***	-8.157418	-8.231749
	-7.934593	-7.840415	-7.912418	***-7.918079***	-7.769569	-7.800805
4	-8.125683	***-8.548763***	-8.182441	-8.171811	-8.250265	-8.177596
	-7.867117	***-8.247102***	-7.837686	-7.783962	-7.819322	-7.703558
5	-8.098753	-8.178533	***-9.014564***	-8.940669	-9.002422	-8.174527
	-7.797092	-7.833778	***-8.626714***	-8.509725	-8.528383	-7.657395

Note: Selected specifications in bold and italic emphasising.

The first value per field always indicates the value for the Akaike criterion, whilst the second gives the value for the Schwartz criterion. A smaller value indicates an improvement in the corresponding selection criterion.

For the presentation we have restricted the number of lags for both the autoregressive and moving average terms to five, as higher order terms do not provide additional improvements in the criteria. We find that the ARMA(5, 2)-process gives the best overall fit to the data. Additionally, we have highlighted those ARMA processes which give the best fit for an imposed shorter maximum lag length. Both criteria correspond for all but one process. In the case of two lags, the Akaike criterion suggests an ARMA(2, 2)-process, whilst the Schwartz criterion points towards the MA(1)-process, which has already been selected for the unit lag specification by both criteria. Hence, we have selected the MA(1), the ARMA(2, 2), the ARMA(3, 3), the ARMA(4, 1) and the ARMA(5, 2)-processes.

The following table gives the estimation results and the characteristic roots for the above selected processes, where processes are presented by column. We have eliminated autoregressive and moving average coefficients that turned out to be insignificant.

Table IIa: ARMA Estimation Results

	MA(1)	**ARMA(2, 2)**	**ARMA(3, 3)**	**ARMA(4, 1)**	**ARMA(5, 2)**
Constant	0.034 (8.23)	0.039 (0.97)	0.031 (4.10)	0.030 (5.00)	0.027 (6.53)
AR(1)	-	0.226 (2.36)	-	-0.614 (-4.13)	0.325 (2.97)
AR(2)	-	0.737 (5.53)	-0.266 (-1.99)	-	-0.669 (-5.99)
AR(3)	-	-	0.609 (4.87)	0.333 (1.88)	0.616 (6.12)
AR(4)	-	-	-	0.449 (3.05)	-
AR(5)	-	-	-	-	0.215 (2.91)
MA(1)	0.460 (3.15)	0.236 (4.53)	0.520 (13.54)	0.969 (29.92)	-
MA(2)	-	-0.746 (-1111)	0.814 (21.18)	-	1.198 (7.76)
MA(3)	-	-	-0.220 (-2.30)	-	-
Dummy75	-0.039 (-2.53)	-0.039 (-2.36)	-0.041 (-2.92)	-0.030 (-2.03)	-0.033 (-2.60)
R^2	0.27	0.40	0.55	0.45	0.68
DW	1.92	1.94	2.19	1.88	2.09
Q - Statistic	20.50	10.97	23.63	14.32	11.54

Note: DW: Durbin-Watson, t-values are indicated in parenthesis below the coefficient value.

Table IIb: ARMA Estimation Results: AR and MA roots

	MA(1)	ARMA(2, 2)	ARMA(3, 3)	ARMA(4, 1)	ARMA(5, 2)
AR Roots		0.98 -0.75	0.74 0.37-0.83i -0.37+0.83i	0.80 -0.27+0.76i -0.27 -0.76i -0.86	0.84 -0.06+0.81i -0.06-0.81i -0.19-0.59i
MA Roots	-0.46	0.75 -0.99	0.22 -0.37+0.92i -0.37-0.92i	-0.97	-0.19+0.59i

Interestingly, up to an order of five, significant explanatory power is added by including higher order autoregressive terms. For all estimations, we find no autocorrelation in the residuals. Note however that the ARMA(2, 2)-process has an autoregressive root close to unity. Moreover, the moving average and autoregressive roots are virtually identical, thus identifying a problem of overspecification for the ARMA(2, 2)-process.

V. Output Persistence in Austria

We have conducted t-tests for the three hypotheses indicated in chapter three. For the perfect competition growth hypothesis, we have additionally conducted a Wald-test. The Wald test is an F-test on the acceptance of a joint null hypothesis, which puts linear restrictions on the coefficient values accordingly.

Table three below gives the results. The first line indicates the sum of autoregressive and moving average coefficients, with the t-statistic for a coefficient sum equal to zero in parenthesis below, following the conventional formula,

$$t = \frac{\sum (a_t + m_t)}{\sqrt{\sum_t \sum_s [\mathrm{cov}(a_t, a_s) + \mathrm{cov}(m_t, m_s) + \mathrm{cov}(a_t, m_s)]}} \qquad \forall s, t \,,$$

where the denominator is simply the root of the sum of the terms in the covariance matrix. The next three lines give critical t-values at the five percent significance level for the corresponding hypotheses. We would accept the null hypothesis for negative autocorrelation (H_o^s) if the actual t-value is below the critical t-value. The null hypothesis for zero autocorrelation (H_o^{pc}) would be accepted if the t-value is between the positive and negative critical t-value given in table III below, whilst non-rejection of the null hypothesis for positive autocorrelation (H_o^{ic}) requires a t-value less than the critical value indicated. The Wald test is presented in the last two lines of table III. We would not reject the null hypothesis for low F-values, or correspondingly high p-values, where we have again selected a 5 % significance level.

Table III: coefficient sums, t-statistics and critical t-values for the three hypotheses

	MA(1)	**ARMA(2, 2)**	**ARMA(3, 3)**	**ARMA(4, 1)**	**ARMA(5, 2)**
$\sum a_i + \sum m_j$	0.460 (3.153)	0.453 (3.503)	1.458 (6.976)	1.165 (4.206)	1.685 (5.933)
Critical Values for the t-test					
H_o^s:	1.691	1.694	1.696	1.693	1.696
H_o^{pc}:	+/-2.031	+/- 2.038	+/- 2.040	+/- 2.036	+/- 2.038
H_o^{ic}:	-1.691*	-1.694*	-1.696*	-1.693*	-1.696*
Wald-test (F-statistic and p-value)					
H_o^{pc}	9.941 (0.0033)	12.281 (0.0013)	48.651 (0.0000)	16.855 (0.0003)	35.220 (0.0000)

Note: Non-rejection of the null-hypothesis is denoted by an asterisk (*)

We find that both the Solow growth model and the perfect competition growth model cannot be accepted empirically, by either the t-test, or, if applicable, by the Wald test as well. The F-value of the Wald test for a zero sum of coefficients is large for all specifications, with a positive coefficient sum. We find a positive sum of autoregressive and moving average terms for all the specifications.

The dominant model emerging from this analysis is the imperfect competition growth model. Apart form the ARMA(2, 2)-process, we find that the sum of AR coefficients is consistently positive and below unity, with values between 0.17 and 0.49. Furthermore we find that the sum of autoregressive and moving average coefficients remains positive, with values between 0.45 and 1.69. The estimated long-run effect of shocks to Austrian GDP therefore exhibits persistence and exceeds the initial shock. We can display these results conveniently by graphing the intertemporal reaction of output to a unit shock to GDP.

Figure I. Impulse response functions and 5 % confidence interval

Figure Ia. MA(1)

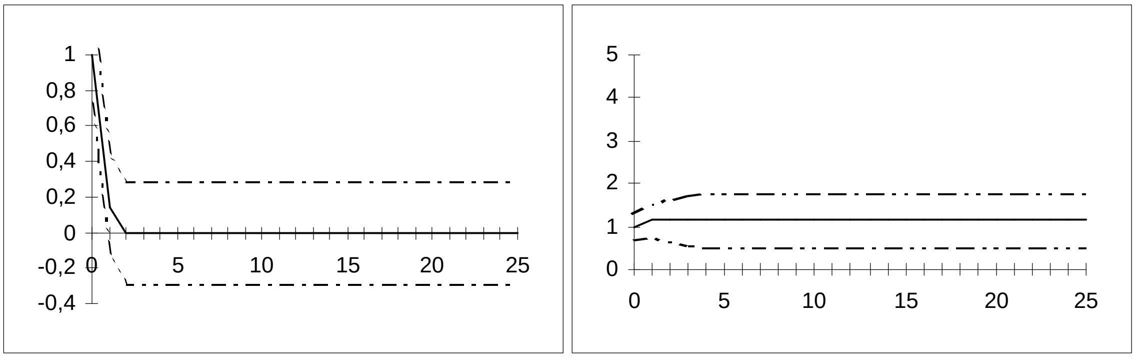


Figure Ib. ARMA(2, 2)

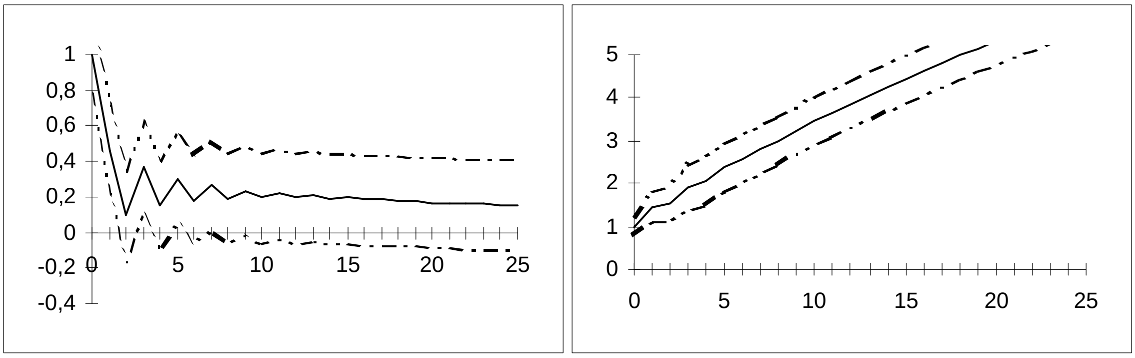


Figure Ic. ARMA(3, 3)

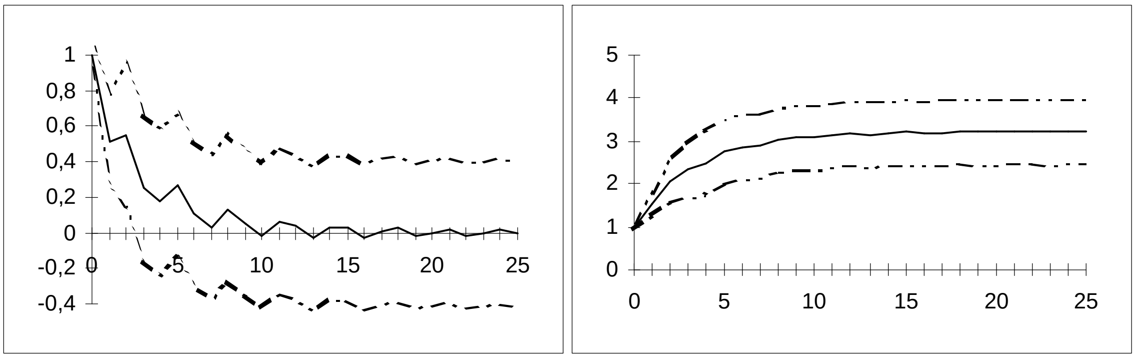


Figure Id. ARMA(4, 1)

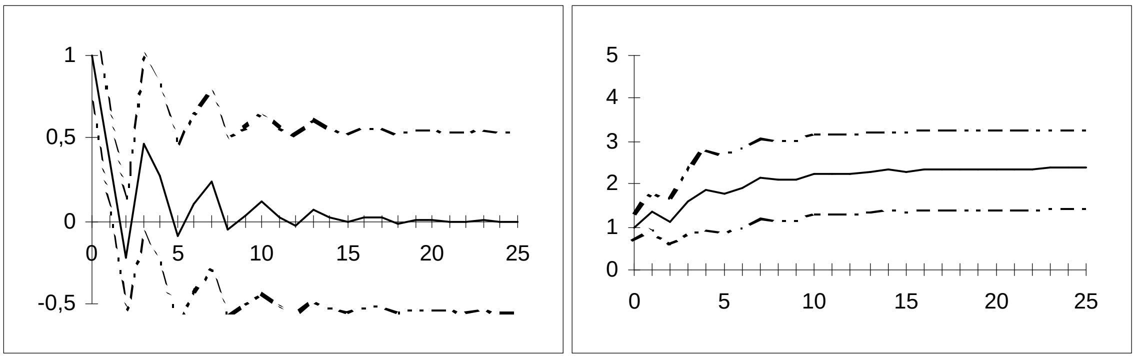
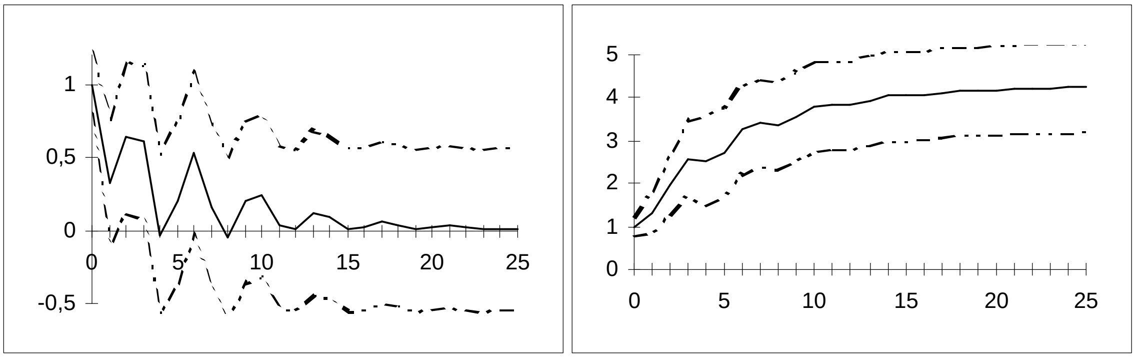


Figure Ie. ARMA(5, 2)



Note: Differences are displayed on the left hand side, levels on the right.

The left hand side graph always shows the response in the GDP growth rate to a unit shock, corresponding to a temporary one percent increase in the growth rate of output. The right hand side gives the effect on the trend adjusted logged level, and hence describes the cumulative percentage change of output following a unit impulse. The most distinct picture above is figure Ib, which represents the nonstationary ARMA(2, 2)-process, which can be most evidently seen from the level representation. Looking at the growth rate representation, the initial impulse declines rather rapidly, falling to an average of 0.2 percent additional growth after only three periods, with some initial oscillation, but remains above 0.1 percent for the entire subsequent time horizon in our graph.

All other specifications share a similar behaviour. After the initial impulse, we do observe several periods of accelerated economic growth, until the effect fades out after at most twelve periods. Of course, the effect on the MA(1)-process ceases after a single period. The compound growth effects add up to 1.46 % for the MA(1)-process, to 3.74 % for the ARMA(3, 3) -process, to 2.60 % for the ARMA(4, 1) and to 5.23 % for the ARMA(5, 2)-process, respectively. All of these specifications correspond nicely to the innovation model of growth, where after an initial impulse, additional multiplicative effects are triggered in the economy.

Interestingly, the economic implications of the ARMA(5, 2)-process, which has been selected by both the Akaike and the Schwartz criterion as the best specification, are similar in direction and speed of convergence with all but one other representation. Only the magnitude of the compound effect differs slightly. This gives strong support for the robustness of our test results with respect to model selection.

One process does not fit into this harmonic picture, namely the ARMA(2, 2)-process, where a transitory impulse leads to a persistent change in the economic rate of growth by one tenth of a percent even after 35 years. One could, of course, easily neglect this phenomenon, and previous studies have done exactly that. Indeed, the time series has passed the Dickey-Fuller and the Phillips-Perron stationarity tests, and nonstationary behavior would clearly contradict these results. Moreover, the process has not even been selected on the grounds of the asymptotically correct Schwartz criterion, just because its long-run behavior is not in line. And finally, it is very likely to be overspecified, and with an R^2 of only 40 % the process has the second least predictive power of the selected representations.

However, the process is in line with new theoretical evidence as presented by Evens, Romer, and Honkapoja. This subclass of a monopolistic competition growth model would predict that output growth rates follow a random walk. A transitory shock may lead agents to believe in a different equilibrium, and lead to perfectly rational eonomic reactions that drive the economy into just that equlibrium. The new equlibrium may well exhibit a different rate of economic growth, which is just what the ARMA(2, 2)-process seems to describe. In reality, instead of remaining in the proximity of the new equilibrium forever, individual expectations may and will change again, possibly returning the economy to the initial equilibrium.

Given that switching is infrequent, we would expect to find structural breaks in the data. Indeed, this is in line with results from Pischke (1991) and Demrey and Duck (1992) for US and international evidence. By contrast, suppose that switching occurs rather frequently, but that the underlying fundamental variable which triggers the switching is unobservable. In that case, one may use the Kalman-filtered series as an instrumental variable, testing a structural two variable VAR model instead. This is, however, beyond the scope of this paper.

VI. Concluding Remarks

The paper has analysed the degree of output persistence in Austrian GDP in order to empirically discriminate between the main four competing theories of economic growth. We find that fluctuations in output are positively autocorrelated, and that a temporary shock in the growth rate induces a permanent larger effect on the level of GDP. We cannot fully rule out the possibility that temporary shocks even induce permanent changes in the growth rate of GDP.

The findings are in clear contradiction with a Solow type growth model, as changes in output today should be reversed in subsequent periods, which is clearly not the case for Austria. Also, the perfect competition approach to GDP growth can be rejected. The intuition behind this result is that an increase in output should lead to a once and for all change in the level of GDP, without further spillover effects. The model which has received the most empirical support in the imperfect competition growth model. Here, an investment multiplier augments an initial increase in GDP through the subsequent optimal reactions of economic agents. The cumulative effect to the output level is permanent and exceeds the initial shock, leaving the long-run equilibrium growth rate unaffected.

The univariate model structure does not allow us to inquire on the nature of shocks to GDP. As the analysed shock is a compound shock, containing both supply and demand components, care has to be given to a traditional multiplier interpretation. This evidently leads to the larger research question of correctly addressing demand and supply shocks. Furthermore, the empirical results cannot fully rule out the possibility of multiple equilibrium growth rates. So far, this stream of literature remains largely unexplored, hence further empirical and theoretical theoretical research along these lines appears to be promising.

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Appendix

A general ARMA(p, q)-process for the growth rate of output, y_t,

$$A(L)\, y_t = M(L)\, e_t,$$

where $A(L)$ is the autoregressive lag polynomial, $M(L)$ is the moving average lag polynomial, and e_t is an i.i.d. random variable, may be transformed into an infinite moving average process of the following type,

$$y_t = [M(L)/A(L)]\, e_t.$$

The Lag polynomials are conventionally defined as,

$$A(L) = 1 - a_1 L - a_2 L^2 - a_3 L^3 - \ldots$$

$$M(L) = 1 + m_1 L + m_2 L^2 + m_3 L^3 + \ldots$$

where a_i is the autocorrelation coefficient of order i and m_j is the moving average coefficient of order j. Setting L to unity, the total long-run impact of a unit shock to output equals,

$$\lim_{t\to\infty} y_t = \frac{M(1)}{A(1)}.$$

Subtracting the initial shock in order to identify discriminating hypotheses,

$$\lim_{t\to\infty} y_t - 1 = \frac{M(1)}{A(1)} - 1 = \frac{M(1) - A(1)}{A(1)},$$

and substituting the expressions for the lag polynomials yields,

$$\lim_{t\to\infty} y_t - 1 = \frac{(1 + m_1 + m_2 + \ldots) - (1 - a_1 - a_2 - \ldots)}{1 - a_1 - a_2 - \ldots} = \frac{\sum_{j=1}^{q} m_j + \sum_{i=1}^{p} a_i}{1 - \sum_{i=1}^{p} a_i},$$

which is the expression in the main text.